FINAL Progress Report

Delta Water Quality

TO:	Erin Foresman/ EPA Project Officer
FROM:	Thomas Jabusch/ ASC Project Manager
PROJECT #:	EPA PRG-DOC ID: CP-00T58601 ASC Project# 8107 "Delta Water Quality" Period of performance: 12/10/2010 – 06/30/2014
DATE:	September 25, 2014
REPORTING PERIOD:	12/10/2010 – 06/30/2014 (project summary as a whole)

Introduction

The U.S. EPA Region 9 has initiated an effort to assess the effectiveness of regulatory mechanisms designed to protect water quality in the San Francisco Bay/Sacramento - San Joaquin Delta Estuary (Bay Delta Estuary). The Aquatic Science Center (ASC) project supports this assessment by evaluating public input, existing information, and providing recommendations for improving water quality and identifying sustainable approaches to water quality management. Completion of this project supports EPA's Strategic Plan Goals 2 and 4, Clean and Safe Water and Healthy Communities and Ecosystems. Specifically, project outputs will be used to achieve environmental outcomes consistent with protecting and improving water quality on a watershed basis and protecting and restoring ecosystems (see Table 1).

Table 1. Summary of project tasks, outputs, and associated environmental outcomes.

Task	Status	Outputs	Associated environmental outcomes
Public Comment Synthesis Report	Completed	– Synthesis of ANPR public comments (Attachment 1)	– Increased understanding of public awareness and concerns about water quality in the Bay Delta Estuary through the ANPR process. – Prioritizing actions to improve water quality based on public input and existing information. – More focused management of Clean Water Act programs including implementing recommendations for removing impairments to aquatic resource designated uses.
Consultation Process	Completed	– LSZ Workshop March 2011	– Prioritizing actions to improve water quality based on public input and existing information. – More focused management

Final Report	Completed	- Review of Scientific Papers and Summary of Key Findings (Attachment 2) - Library of scientific papers - Workshop summary (Attachment 3)	of Clean Water Act programs including implementing recommendations for removing impairments to aquatic resource designated uses.
Pulse of the Delta	Completed	- Pulse of the Delta 2012	- Better water quality information and management through support for a regional monitoring program.
Project Management	Completed	- Progress reports	n/a

Summary of Project Activities

The contract period for this EPA grant ended on June 30, 2014. All project deliverables were completed during this reporting period and are delivered with this final project progress report. During this project the SFEI staff and project partners

1) Prepared a synthesis report of public comments regarding water quality issues in the Bay Delta Estuary based on responses to the Advanced Notice of Proposed Rulemaking (ANPR) for Water Quality Challenges in the Bay Delta Estuary,
2) Co-facilitated with EPA a Technical Workshop on Estuarine Habitat in the Bay Delta Estuary (Task 2), and
3) Prepared a report, “Pulse of the Delta”, which presents project conclusions and recommendations as well as other Delta water quality information in a format (Task 4).

Project Task Accomplishments

Task 1.0 Public Comment Synthesis Report

The purpose of this task was to develop an understanding of public awareness and public priorities regarding water quality issues in the Bay Delta Estuary. ASC summarized and evaluated public comments received through the ANPR for Water Quality Issues in the Bay Delta Estuary process. The task resulted in a summary of public comments including basic statistics (number of comments, from what types of commenters, how many comments per question, etc.) and a narrative synthesis.

Task Output

- A synthesis report of public comments (**Attachment 1)** regarding water quality issues in the Bay Delta Estuary based on responses to the Advanced Notice of Proposed Rulemaking (ANPR) for Water Quality Challenges in the Bay Delta Estuary**.**

Task 2.0 Consultation Process (100% complete)

The objective of this task was to help refine, further develop, and advance recommendations for actions that address estuarine habitat issues by holding a technical workshop involving scientists with recognized expertise in Bay-Delta estuarine habitat.

SFEI and project partners convened a Technical Workshop on Estuarine Habitat in the Bay Delta Estuary to assess the state of the science on the relationships of X2, the low salinity zone, and the ecological community of the Bay Delta Estuary.

The workshop informed the development of the EPA SF Bay Delta Action Plan, which identifies priority EPA actions for improving beneficial use protection and water quality.

Task Outputs

- A Technical Workshop on Estuarine Habitat in the Bay Delta Estuary was held on March 27, 2012.
- ASC produced a Review of Scientific Papers and Summary of Key Findings that condenses baseline ecological knowledge of the estuary into an easily accessible document (**Attachment 2)**.
- Workshop speakers' presentations and a LSZ Workshop Summary (**Attachment 3**) were provided to the project manager and are posted to the EPA website.

Task 3.0 Final Report (100% complete)
The Technical Workshop on Estuarine Habitat in the Bay Delta Estuary served to characterize the state of science regarding the response of selected biological indicators and ecological processes to changing locations of the low salinity zone in the Bay Delta Estuary. To this end, ASC prepared three associated products in lieu of a final project report, per discussion with the EPA Grant Manager.

Task Outputs

- Review of Scientific Papers and Summary of Key Findings (submitted March 2011, attached), Attachment 1.
- Library of scientific papers, including some that were scanned, which can be downloaded and viewed at files.sfei.org (Username: X2workshop, Password: 27March2012)
- Workshop summary (attached).

Task 4.0 Pulse of the Delta (100% complete)
The Pulse of the Delta 2012 presented ANPR conclusions and recommendations in a format accessible to a wide audience. The Pulse of the Delta was produced in cooperation with the Central Valley Regional Water Quality Control Board to support the Delta Regional Monitoring Program (RMP)'s goals of better defining water quality issues of regional concern and making water quality monitoring information more useful and accessible.

The Pulse of the Delta 2012 is publicly available through several websites, including the homepages of ASC (http://www.asc.org) and San Francisco Estuary Institute (http://www.sfei.org), and the Central Valley Water Board's Delta RMP webpage (http://www.waterboards.ca.gov/centralvalley/water_issues/delta_water_quality/comprehensive_monitoring_program/2012_pulseofthedelta.pdf).

The publication of the Pulse of the Delta 2012 helped to achieve the project outcome of better water quality information and management through support for a regional monitoring program. It features a contribution on the U.S. EPA's Action Plan titled "USEPA Completes Delta Stressor Investigation". The Pulse of the Delta 2012 also introduced a new status and trends section with updates on important monitoring results and leading indicators for the Delta.

Task Outputs

- Publication and public release of Pulse of the Delta 2012. It is not attached here due to its very large electronic file size.
- Summary article in the Pulse of the Delta 2012 highlighting key findings from EPA's Delta Clean Water evaluation
- Status and trends section with updates on important monitoring results and leading indicators for the Delta)

- Additional feature articles (Methylmercury research findings, Interagency Ecological Monitoring Program) and management updates (Delta RMP development, Numeric Nutrient Endpoint Framework).

Task 5.0 Project Management (100% complete)
SFEI staff performed general project management tasks including project progress reporting, invoicing, coordination of staff and project partners on all tasks, project tracking, and sub-contract management. During the last reporting period, SFEI completed the final invoicing, finalized the project accounts and subcontracts, and conducted other final project closeout tasks.

Task Outputs

- With this final project progress report, the project workplan and all progress reports have been submitted to the Grant Manager. Copies of project subcontracts are available upon request.

Project Milestone Tracking

Tasks	Milestones	%Complete	Submitted
Public Comment Synthesis Report Formation of SRT Selection of a Demonstration Watershed.	Outline	100	2-2011
	Detailed Outline	100	5-2011
	First draft	100	6-2011
	Final report	100	7-2011
Consultation process	Outline	100	12-2011
	Draft synthesis report	100	3-2012
	Final report	100	3-2012
Final report	Outline	100	3-2012
	Draft synthesis report	100	4-2012
	Final report	100	4-2012
Pulse of the Delta	Advisory group	100	8-2011
	Final outline	100	10-2011
	Draft articles	100	12-2011
	Editorial review comments to authors	100	1-2012
	Revised drafts to advisory group	100	3-2012
	Draft of laid-out version	100	7-2012
	Final proofs	100	9-2012
	Printed Pulse of the Delta	100	9-2012
Project management	Progress reports	100	9-2014
	Meetings with EPA	100	3-2014

Project Cost Summary

Task #	Description	Cost
1	Public Comment Synthesis Report	$ 39,783
2	Consultation Process	$ 49,462
3	Final report	$ 2,223
4	Pulse of the Delta	$ 85,193
5	Project Management	$ 17,113
Project TOTAL		$ 211,737
Project BUDGET		$ 211,760
Project Balance		$ 23

Attachment 1 of Final Report: Synthesis of Public Comment

Appendix II Synthesis of Public Comment

---

on the Advance Notice of Proposed Rulemaking for
Water Quality Challenges
in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary

A Report to the
United States Environmental Protection Agency
June 2012

Thomas Jabusch
Aquatic Science Center

TABLE OF CONTENTS

Table of Contents ii
Executive Summary iii
INTRODUCTION 1
Request for Public Comment 1
About the Respondents 2
Main Themes that Emerged from the Responses 3
GENERAL COMMENTS 5
CONTAMINANTS 7
Ammonia: Toxic and Nutrient Effects 11
Selenium 14
Pesticides 20
Contaminants of Emerging Concern 35
PROTECTING ESTUARINE HABITAT, FISH MIGRATION CORRIDORS AND WETLANDS 37
Estuarine habitat 38
Fish Migration Corridors 46
Wetlands 50
Conclusion 52
Appendices 56
Appendix A: Tables 57
Appendix B: List of Respondents 73

EXECUTIVE SUMMARY

In February 2011, the U.S. Environmental Protection Agency (EPA) released an Advance Notice of Proposed Rulemaking (ANPR) to assess whether current regulatory mechanisms (including standards for toxics, nutrients, and estuarine habitat protection) are effective in protecting water quality and aquatic life in the Bay Delta Estuary and its tributaries. The ANPR sought public input on whether the EPA should be taking new or different actions under its programs to address water quality challenges affecting fish and other estuarine resources.

EPA sought comments on specific topics and questions related to contaminants (ammonia, selenium, pesticides, contaminants of emerging concern) and aquatic habitat (estuarine habitat, fish migration corridors, wetlands). Interested parties were encouraged to read the Unabridged ANPR *Water Quality Challenges in the San Francisco Bay/Sacramento-San Joaquin Delta*, available at the EPA.gov website, and to provide additional technical information and suggestions for EPA actions.

Altogether, 55 respondents submitted comments, including individual respondents, representatives of various sectors of government, various types of membership associations, and non-governmental organizations (NGOs). Most of the key stakeholder groups are represented in the group of respondents, including state and federal agencies, water use agencies, regulated dischargers, environmental groups, commercial fishing, recreational boating, and local government. More than half the comments are substantive indicating respondents had technical expertise and familiarity with water quality regulations.

Several main themes emerge from the public comments:

- Several stakeholder groups support an EPA evaluation of aquatic life protection by Clean Water Act (CWA) programs in the Bay Delta Estuary as a timely action, but some groups identify concerns over the possibility of additional regulations.

- Respondents call for a comprehensive regional monitoring program for the Delta and urge EPA to actively support it.

- Respondents express concerns about EPA's focus on point of discharge regulation, water quality criteria, and specific permit requirements. Respondents want to see more focus on pollution prevention by means of source control.

- Many respondents identify a regulatory gap that allows legal registration and application of pesticides under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) that subsequently cause water quality problems, which are regulated by the Clean Water Act (CWA). Respondents describe concerns about aquatic toxicity from legally applied pesticides and want EPA to address this internal program issue.

- Various interest groups see the development of wildlife and aquatic life criteria for selenium as an opportunity for addressing science and regulatory gaps, if based on new information on environmental processes in the estuary.

- Several respondents identify mercury as an important issue that the ANPR does not specifically address. They would like to see the issue more fully addressed, especially loadings, methyl mercury production, and fish tissue levels.

- Several commenters support nutrient numeric endpoints (NNEs) for the Delta, ammonia criteria focused on spring phytoplankton inhibition, and a broader analysis of nutrients beyond ammonia and its toxicity.

- Respondents want EPA to address contaminants of emerging concern (CECs) at the source. For example, during the registration of a product, or as an integral part of research, development, and product testing, before such products are publicly available.

- Commenters representing federal resource agencies, an environmental organization, and a wastewater discharger propose various success measures for salmonid migration in Central Valley streams. Commenters highlight the incomplete and dated nature of information about migration dynamics of adult San Joaquin salmon.

- Commenters disagree on the issue of estuarine habitat and the use of a salinity gradient with compliance points as the regulatory structure to protect estuarine fish species.

- Some respondents recommend protecting wetlands by focusing regulatory action on restoring ecological wetland functions.

The views expressed in the synthesis report are from the individuals and organizations that participated in the public comment process. They reflect concerns over future policy decisions affecting the Delta and its values as a resource. Since a number of respondents prepared detailed, substantive comments (respondents submitted 640 pages of comments, in total, plus numerous references and supporting materials), we strongly encourage interested parties to examine the full, unedited record of public comment at http://www.epa.gov/sfbay-delta/actionplan.html.

INTRODUCTION

The Advance Notice of Proposed Rulemaking (ANPR) for Water Quality Issues in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay Delta Estuary) is part of a comprehensive set of commitments made by Federal agencies to address California water issues under the Interim Federal Action Plan released in December 2009. The purpose of the ANPR is to help the U.S. Environmental Protection Agency (EPA) assess whether the current regulatory mechanisms designed to protect aquatic life and water quality in the Bay Delta Estuary and its tributaries are effective, including standards for toxics, nutrients, and estuarine habitat protection.

EPA used the ANPR to seek public input on whether to take new or different actions to address water quality challenges affecting fish and other estuarine resources. The public comment will inform EPA's assessment and possible follow up actions.

The comment period opened on February 22, 2011, and ended on April 25, 2011. This document provides a synthesis of the public comment.

REQUEST FOR PUBLIC COMMENT

EPA provided options for submitting comments electronically at the Federal Rulemaking Portal, by email, or by hardcopy. Interested parties were encouraged to read the Unabridged ANPR *Water Quality Challenges in the San Francisco Bay/Sacramento-San Joaquin Delta* and provide additional technical information and suggestions for EPA actions. EPA sought comments on specific topics, and specific questions on each topic:

- Contaminants
- Ammonia: Toxic and Nutrient Effects
- Selenium
- Pesticides
- Contaminants of Emerging Concern
- Estuarine Habitat
- Fish Migration Corridors
- Wetlands

EPA released the ANPR on February 10, 2011, and simultaneously issued a press release. On the same day, EPA's Bay-Delta team posted information about the ANPR and relevant documents on EPA's San Francisco Bay Delta Estuary website and distributed email announcements to relevant mailing lists.

ABOUT THE RESPONDENTS

Respondents provided optional information about themselves by entering fields in the electronic submittal form or, more informally, in submitted cover letters and emailed comments. This information was used to characterize respondents by sector, perspective, and interest and involvement in the Delta. While this data-gathering method is not scientific, it provides a general picture of who responded and how.

Total Response

Fifty-five (55) respondents submitted comments. The majority of respondents (51) submitted comments electronically (Federal Rulemaking Portal, email, or both). All submissions were original and no form letters were used. Of the 55 respondents, 37 respondents submitted prepared letters. Twenty-one respondents submitted additional information as uploaded files, hardcopies, or on a CD. About a quarter of the total response (14) consisted of brief general comments or email messages.

See also Appendix A, Table 1.

Sector

Thirty-two respondents (60%) identified themselves as representatives of various organizations. The top sectors represented were government, various types of membership associations, and non-governmental organizations (NGOs), which together accounted for 54% of the total response.

The fifteen government responses represented various levels of government, with four respondents each affiliated with federal, state, and regional agencies, and three with local agencies. This breakdown includes one presumably mislabeled comment (organization: "Student"[1], agency: federal).

About 40% of respondents were private individuals and/or small business owners representing the private sector.

See also Appendix A, Table 2, 3, and 4.

Perspective

Non-affiliated individuals and small businesses comprised 38% of respondents. The bulk of this group provided general comments and only 2 of the 21 comments directly answered the specific questions in the ANPR.

Respondents representing an organization (62% of respondents) included policy makers, planners, and resource managers (9), environmental advocates (6), regulated dischargers (6), water agencies (4), regulatory agencies (3), consultants (2), water users (2), a commodity group (1), and a research institution (1).

See also Appendix A, Tables 5 and 6.

Interest and Involvement in the Delta

By volume, self-representation and the general public interest (grouped as public involvement) were respondents' primary cited interest (25), followed by natural resource management (7), water supply (7), environmental protection (5), wastewater (3), agriculture (2), stormwater (2), boating (1), land

1 EPA-R09-OW-2010-0019

use (1), renewable energy (1), and science (1).

Accordingly, a large number of the responses were personal comments of individuals (12) or representing a small business or an industry (11). Other responses were from entities involved in the Delta as authorities at the regional (9), local (5), statewide (5), or national level (4), or as environmental (6) or recreational groups (1).

See also Appendix A, Tables 7, 8, 9, and 10.

MAIN THEMES THAT EMERGED FROM THE RESPONSES

The request for public comment was organized around specific questions related to some of the most significant water quality issues affecting aquatic life designated uses in the Bay Delta Estuary. These water quality topics and questions are also the framework for organizing this synthesis report. All submitted comments were systematically reviewed to summarize the main points emerging from the responses. To best capture the main points and nuances of comments, the summary draws extensively from selected direct quotes. The views expressed in the synthesis report are from the individuals and organizations that participated in the public comment process. They are not the views of EPA or Aquatic Science Center. No random sampling was performed, so the record of public comment represents the opinions of people and organizations that participated in the public comment process and not necessarily the opinions of Bay Delta stakeholders as a whole. Views from most of the key stakeholder groups, however, are represented.

Several main themes emerge from the public comment process:

- Several stakeholder groups support this new Bay Delta initiative as a timely action, but by the same token, voice concerns over the possibility of additional regulations.

- Respondents call for a comprehensive regional monitoring program for the Delta and expect EPA to actively support it.

- Respondents expressed concerns about EPA's focus on point of discharge regulation, water quality criteria, or specific permit requirements. Respondents want to see more focus on pollution prevention by means of source control.

- Many respondents are concerned about the regulatory gap that allows pesticides that are causing water quality problems and are regulated by the Clean Water Act (CWA) to be sold and used under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and want EPA to address this issue.

- Various interest groups see the development of wildlife and aquatic life criteria for selenium as an opportunity for addressing science and regulatory gaps, if based on new information describing environmental processes the estuary.

- Several respondents identify mercury as an important issue that the ANPR does not specifically address. They would like to see the issue more fully addressed, especially loadings, methylmercury production, and fish tissue levels.

- Several commenters support nutrient numeric endpoints (NNEs) for the Delta, ammonia criteria focused on spring phytoplankton inhibition, and a broader analysis of nutrients beyond ammonia and its toxicity.

- Respondents want EPA to address contaminants of emerging concern (CECs) at the source. For example, during the registration of a product, or as an integral part of research, development, and product testing, before the product is released on the market.

- Commenters representing federal resource agencies, an environmental organization, and a wastewater discharger propose various success measures for salmonid migration in Central Valley rivers and streams.

- Commenters disagree on the issue of estuarine habitat and the use of a salinity gradient with compliance points as the regulatory structure to protect estuarine fish species.

- Some respondents recommend protecting wetlands by focusing regulatory action on restoring ecological wetland functions.

GENERAL COMMENTS

Thirty of the 55 respondents answered the specific questions asked in the ANPR. While several respondents answered all questions, others chose to selectively answer one or several questions. In addition, 50 of 55 respondents provided general comments that did not address specific questions in the ANPR.

Commenters broadly support a more effective use of existing regulatory authority and a stronger role for EPA in providing technical, scientific, and management guidance. A representative statement, regarding EPA's options for ensuring water quality protection, is: "Rather than undertaking new regulatory initiatives aimed at water quality criteria for specific contaminants, we encourage EPA to assist the State and local agencies to address emerging issues through improved science, public awareness, and cooperative problem solving."[2] Another respondent, in a representative statement, "…looks to EPA as a leader by taking an independent look at the panoply of issues impacting the Bay-Delta today and providing its scientific expertise as a necessary component of comprehensive solution to these problems."[3] Various individuals and groups call on EPA to more rigorously enforce statutory and regulatory authorities, for example, one group concludes "… with a strong recommendation that EPA use its regulatory authority to ensure that regulations affecting water quality in the Delta are enforced at every level."[4]

A number of respondents are wary about possible new regulations. A local government representative captured this sentiment when stating that, "We believe the existing regulatory framework, led by the Water Boards, is well suited and has been effective to date in addressing water quality concerns."[5] Another respondent made a related point:

2 CASA, BACWA, CVCWA, Tri-TAC, SCAP (EPA-R09-OW-2010-0034.1)
3 Contra Costa County Department of Conservation and Development (EPA-R09-OW-2010-0049)
4 Coalition for a Sustainable Delta (EPA-R09-OW-2010-0043.1)
5 Sacramento Regional County Sanitation District (EPA-R09-OW-2010-0022.1)

> Any change in EPA activities must be dependent on existing authority and the availability of existing or new resources.[6]

A number of commenters cited the development of a comprehensive regional monitoring program for the Delta as a priority, usually with an expectation for EPA to fund it. The following two comments express a common refrain:

> It is also true that "i[t] is difficult to evaluate and address contaminants in the Bay Delta Estuary in the absences of a comprehensive monitoring program" (p. 21). For this reason, the US EPA should promote efforts to improve contaminant monitoring, assessment, and reporting within the estuary.[7]

> We cannot stress enough the importance of EPA's continued support, including funding, for our Regional Monitoring Program (RMP), for the newer Delta RMP, and for continued efforts to integrate all monitoring activities across the San Francisco Bay Estuary.[8]

A water district representative stated another widely supported view: "Multiple stressors are at work, and it is this broader set of causes that an effective regulatory response must address."[9] That said, even though comments arrive at this conclusion from different perspectives, the arguments underpinning it differ widely, especially with respect to regulating flow. One view is: "Solving the issues presented by this complex estuary therefore requires a holistic, multi-faceted solution. At the same time, solutions for the Bay Delta must be based on sound scientific analysis that look[s] beyond the tired approaches that have focused exclusively on water exports and flow."[10]

Other comments contest this view, saying that flows need to become a more explicit part of water quality regulation. An environmental organization urges EPA to "mandate that states list waterways impaired by altered flows, and ensure that states take appropriate action to address the impacts to beneficial uses associated with those altered flows."[11]

Several respondents voiced concerns over proposed actions that would focus primarily on contaminants and call for a more holistic approach:

> Considering the variety of potential stressors in the Delta, and the amount of research that has already occurred, it is unlikely that one or two contaminants are responsible for the observed decline in some pelagic species. A weight of evidence approach that considers all stressors, not just contaminants, but also flow, habitat, nutrient status and biological stressors (e.g., introduced species or pathogens) is necessary to find a solution.[12]

Local residents and commenters from local organizations uniformly share concerns over the extent of water exports and its impacts on the Delta:

> It is essential that the Delta continue to receive fresh waters and that they not be

6 County of Sacramento (EPA-R09-OW-2010-0020.1)
7 San Luis Delta & Mendota Water Authority, State Water Contractors (EPA-R09-OW-2010-00 38.1)
8 San Francisco Bay Regional Water Quality Control Board (EPA-R09-OW-2010-00 42.1)
9 Westlands Water District (EPA-R09-OW-2010-00 37.1)
10 Westlands Water District (EPA-R09-OW-2010-0037.1)
11 California Coastkeeper Alliance (EPA-R09-OW-2010-0025.1)
12 Western Plant Health Association (EPA-R09-OW-2010-0036.1)

> diverted or drained. The Delta is made up of a delicate eco-system that is grossly taxed by freshwater diversion and sales of water to other consumers.[13]

For these and other reasons, many respondents urge that EPA remain actively involved in the Bay Delta Conservation Plan (BDCP) process:

> EPA's environmental review of BDCP should ensure that the BDCP process and associated analyses adequately address water quality concerns. While EPA's involvement in BDCP may be limited in light of resource constraints, EPA's participation will ensure a more effective and efficient BDCP review process and ultimately lead to a better outcome consistent with California's co-equal goals for the Bay-Delta.[14]

CONTAMINANTS

Eight respondents answered questions on general contaminant issues, including regulated dischargers (3), environmental organizations (2), resource agencies (2), and a local business (1).

Key Points

- ⇨ Mercury emerges as an additional priority issue for continued, focused review.
- ⇨ Respondents are skeptical about the usefulness of pollutant-specific water quality criteria in addressing interactive effects between multiple contaminants and other physical, chemical, and biological stressors.
- ⇨ Respondents want EPA's follow up actions to focus on source control rather than the point of discharge.
- ⇨ One of the few suggested information sources on the possible impacts of climate change on pollution is the *2009 California Climate Change Adaptation Strategy*.

1. **Are there contaminants, other than those named above, causing adverse impacts to aquatic resource designated uses in the Bay Delta Estuary and that should receive more focused review?** (5 answers)

All five answers to the first question identify mercury as a priority issue. "Mercury is a key concern in the Bay Delta Estuary, primarily due to levels of mercury in fish tissue that can impact both human health and wildlife," comments a local government representative. "As management decisions are made, and projects implemented, that affect the estuary, EPA and other regulators should consider the potential effects of these decisions and projects on mercury entering the food chain."[15]

A federal agency representative made the following related point:

13 Crisi Matthews Real Estate (EPA-R09-OW-2010-0003)
14 Natural Resources Defense Council (EPA-R09-OW-2010-0027.1)
15 County of Sacramento (EPA-R09-OW-2010-0020.1)

EPA should consider mercury in its reviews. Through the TMDL process, the State of California has begun a five-year process focused on developing BMPs to control or reduce methylmercury production. We are hopeful this effort will provide tools to address methylmercury concerns and recommend EPA consider results of this process as well. We believe it would be a significant achievement to reduce methylmercury production to levels recommended in the Delta TMDL, while simultaneously implementing wetland creation and restoration recommended by the Central Valley Project Improvement Act (CVPIA), CALFED Bay-Delta Program (CALFED), Bay-Delta Conservation Plan (BDCP), and Delta Vision.[16]

Addressing the methylization of mercury in wetlands is seen as critical, as well as mercury loads emanating from upstream mines, and human exposure risks based on fish consumption. In different versions, the following remark represents a common thread through public comments: "While not directly associated with the plummeting fish populations in the region, mercury levels in the Delta, its tributaries, and San Francisco Bay have lead to numerous listings on the 303(d) list due to bioaccumulation in fish tissue. Consequently, mercury loads pose a significant health risk to both wildlife and human fishing populations."[17]

2. **How can pollutant-specific water quality criteria effectively address or incorporate interactive effects between multiple contaminants and other physical, chemical, and biological stressors?** (4 answers)

All four answers to the question are skeptical about the usefulness of pollutant-specific water quality criteria in addressing interactive effects between multiple contaminants and other physical, chemical, and biological stressors: "The potential combinations of registered pesticides and chemicals, the exposure potential and ultimate toxicities are clearly too large to effectively address"[18] states one of the respondents in a version of what is a common notion in the answers.

Respondents made the following key statements:

Water quality criteria cannot be used effectively to address interactive effects until a robust scientific understanding of multiple stressor effects in the estuary is developed.[19]

Contaminant threshold levels below the lethal level (LC50s) should be considered (e.g. EC50s, or EC25s). Studies that document synergistic effects for two compounds found in the Bay-Delta system should be used to set contaminant thresholds. ... Also, adequate freshwater flows will tend to reduce concentrations of all interacting contaminant compounds and thereby reduce their individual and synergistic effects.[20]

The California Office of Environmental Health and Hazard Assessment recently issued a report titled "Cumulative Impacts: Building a Scientific Foundation" that provided a road map for identifying cumulative impacts across several exposure media. In addition, EPA itself is revising its process for regulating drinking water

16 US Fish and Wildlife Service (EPA-R09-OW-2010-0052.1)
17 Clean Water Action (EPA-R09-OW-2010-0044.1)
18 US Fish and Wildlife Service (EPA-R09-OW-2010-0052.1)
19 County of Sacramento (EPA-R09-OW-2010-0020.1)
20 The Bay Institute (EPA-R09-OW-2010-0040.4)

contaminants by developing regulations based on "families" of contaminants.[21]

> One of the objectives of FIFRA is to ensure pesticides "will not cause unreasonable harm to the environment", thus allowing some harm to occur. During registration, the EPA evaluates each pesticide individually. While a single pesticide may not cause unreasonable harm, mixtures of multiple pesticides, on purpose or in the environment after use, can cause unreasonable harm…We believe the best way to resolve this concern is through efforts to keep pollutants from entering sensitive environments entirely. We recommend EPA evaluate its registration process, education efforts, regulatory avenues and best management practices to determine which would effectively reduce or eliminate non-target pesticide toxicity.[22]

3. **What methods can be used in developing and implementing TMDLs to effectively address or incorporate interactive effects between multiple contaminants and other physical, chemical, and biological stressors on individual water bodies or for water bodies within a watershed?** (6 answers)

The answers to question 3 want the focus to be more on source control rather than the point of discharge. An environmental justice organization "recommends that source control, not just by stopping the flow of contaminants into our waters, but by stopping their use so that they have no way to enter the environment, become a stronger priority in addressing water quality."[23] Or a federal agency representative, relating concerns over the health of fish and wildlife resources: "The most effective way to reduce the effects of multiple contaminants is to minimize the overall levels of pollutants that enter the environment/water in the first place."[24]

The pollutant-by-pollutant approach of Total Maximum Daily Loads (TMDLs) is another key concern across the answers:

> While TMDLs have the potential to drive many water quality improvements, they are limited by their focus on individual contaminants and geographical sections…Measures to address interactive effects between multiple contaminants and stressors in individual as well as multiple water bodies will require EPA and the State to employ a broader systemic approach to address water quality impairments and violations, of which TMDLs are only a part.[25]

> Using ambient water for testing is one way to address interactive effects in a TMDL. Grouping of pollutants under one TMDL based on physical/chemical properties of the constituents is another possible way to incorporate interactive effects.[26]

4. **What information exists about how climate change impacts will effect contaminant pollution (generally or for individual contaminants)?** (3 answers)

Three respondents provide references that address implications of climate change on contaminant issues facing the Delta. A state agency representative cited the 2009 *California Climate Change Adaptation Strategy*, which "discusses cross-sector impacts, such as mosquito abatement for public

21 Clean Water Action (EPA-R09-OW-2010-0044.1)
22 US Fish and Wildlife Service (EPA-R09-OW-2010-0052.1)
23 Clean Water Action (EPA-R09-OW-2010-0044.1)
24 US Fish and Wildlife Service (EPA-R09-OW-2010-0052.1)
25 Clean Water Action (EPA-R09-OW-2010-0044.1)
26 Sacramento Regional County Sanitation District (EPA-R09-OW-2010-0022.1)

health and the biological [e]ffects to fish, migratory birds, and food chain, as well as threats from contamination/pollution expected from flooding of farms and infrastructure." The answer continues, "it is thought that higher temperatures together with flooding will likely increase algae blooms, which can lead to more wildlife diseases (e.g., avian botulism) and affect dissolved oxygen and fish survival."[27] The answer also suggests a greater prevalence of diseases such as West-Nile virus and avian influenza and a subsequent increase in the application of insecticides and other chemicals that could then affect fish and wildlife.

AMMONIA: TOXIC AND NUTRIENT EFFECTS

Eight respondents answered questions on ammonia, including regulated dischargers (3), resource agencies (2), water agencies (2), and an environmental organization (1).

Key Points

- ⇨ The ANPR provides a thorough and up-to-date summary of the existing information on ammonia in the Bay Delta.
- ⇨ Respondents cite three types of information in support of Delta specific ammonia standards: 1) ammonia toxicity to Delta copepods, 2) ammonia inhibition of diatoms, and 3) studies worldwide that describe the effects of changing nutrient dynamics on aquatic ecosystems.
- ⇨ The answers support the development of Numeric Nutrient Endpoints (NNE) for the Delta.
- ⇨ Runoff from irrigated agricultural lands and confined animal feeding operations are potential sources of ammonia nitrogen that have not been sufficiently assessed.

1. **What, if any, information is available on the sources or impacts of total ammonia nitrogen in the Bay Delta Estuary that is not reflected or cited above?** (5 answers)

For the most part, the respondents cite information sources that had previously been available, presented, and reviewed to evaluate the ammonia issue. Some respondents cite information that challenges existing hypotheses on the potential impacts of ammonia:

> No independent reviews of the potential impact of ammonia on the Delta have led to a consensus that ammonia, or other nutrients, are a key driver of ecological problems in the Delta, including the pelagic organism decline.[28]

Other commenters cite information that supports the development of Delta specific criteria for ammonia, as discussed below (Ammonia Questions 2 and 3).

2. **Is there any information available that suggests site-specific water quality standards for total ammonia nitrogen in the Bay Delta Estuary may be more effective than current standards due to unique hydrological, chemical, biological, or physical conditions?** (2

27 California Natural Resources Agency (EPA-R09-OW-2010-0054.1)
28 Sacramento Regional County Sanitation District (EPA-R09-OW-2010-0022.1)

answers)

Respondents cite local studies reporting ammonia toxicity to Delta copepods and ammonia inhibition of diatoms, and the global literature base documenting the adverse impacts of changing nutrient regimes to aquatic ecosystems, in support of site-specific ammonia standards:

> As the Bay-Delta ANPR correctly notes on page 26: "[r]ecent independent investigations in the Bay Delta Estuary raise the possibility that the 1999 EPA ammonia criteria may not be protective of pelagic species in the Bay-Delta Estuary." The recent life-cycle tests by Teh et al. (2011) with *Pseudodiaptomus forbesi* provide additional support for this conclusion.[29]
>
> There are no current standards that protect the Bay-Delta Estuary from the inhibitory effects of ammonium observed by Wilkerson *et al.* (2006) and Dugdale *et al.* (2007). EPA should develop or participate in the development of nutrient standards to protect the Bay-Delta Estuary from the inhibitory effects of ammonium.[30]
>
> There are no current standards that protect the Bay-Delta Estuary from detrimental shifts in aquatic community composition precipitated by changing nutrient forms and ratios from anthropogenic loadings of nutrients. US EPA should participate in the development of nutrient standards for the Bay-Delta Estuary that restore nutrient forms and ratios to levels that were observed prior to the changes in the community composition observed in the Bay-Delta Estuary over the last few decades.[31]

3. **What information is needed to determine effective site-specific water quality standards for total ammonia nitrogen, including narrative or numeric criteria?** (2 answers)

The two answers focus on the inhibitory effects of ammonia on phytoplankton production:

> Dugdale and Marchi (2010) developed a model that can be used to calculate numeric criteria for total ammonia nitrogen to protect against the inhibitory effects of ammonium.[32]
>
> Dr. Dugdale's work (identified in response to question 1) suggests spring phytoplankton blooms are prevented at [concentrations at or below] 4 μM/L and inhibition may begin [at concentrations] as [low] as 1 μM/L. Laboratory and in situ experiments are needed to evaluate and establish necessary protective numeric criteria.[33]

Both answers suggest evaluating numeric nutrient criteria for the Delta[34], using EPA's *Technical Approach To Develop Nutrient Numeric Endpoints for California Estuaries* as guidance. One of the respondents suggests to use "nitrogen and phosphorus levels from times and places when or where the Delta Estuary aquatic community resembled more desirable conditions (e.g. a diatom-calanoid copepod-pelagic fish food web) … to determine numeric criteria for N:P and NO_3:NH_4. …Alternatively, N:P conditions upstream of major anthropogenic inputs of nutrients into the system

29 San Luis Delta & Mendota Water Authority, State Water Contractors (EPA-R09-OW-2010-00 38.1)
30 San Luis Delta & Mendota Water Authority, State Water Contractors (EPA-R09-OW-2010-00 38.1)
31 San Luis Delta & Mendota Water Authority, State Water Contractors (EPA-R09-OW-2010-00 38.1)
32 San Luis Delta & Mendota Water Authority, State Water Contractors (EPA-R09-OW-2010-00 38.1)
33 US Fish and Wildlife Service (EPA-R09-OW-2010-0052.1)
34 NNEs are currently being developed for San Francisco Bay (McKee et al. 2011).

could be used as a target. A third alternative would be to use nutrient conditions in the Liberty Island area where a desirable pelagic community exists as a target condition."[35]

4. **What information is available on nonpoint sources of total ammonia nitrogen and how they may most effectively and efficiently be controlled?** (3 answers)

Two of three answers directly address the question and both identify runoff from agricultural fertilizer application and animal waste as potential sources of ammonia to the Bay Delta. Respondents identify lack of information and regulatory gaps as constraints. One respondent, representing a federal resource agency, states that the agency is "not aware of any efforts to quantify these sources or identify ways to reduce their presence in runoff in the Central Valley."[36] According to a second answer, "ammonia nitrogen in the Delta cannot be effectively controlled until agricultural sources – both irrigated agriculture and confined animal feeding operations - are identified and monitored. Unfortunately, while the Central Valley Regional Water Quality Control Board is in its third year of regulating nonpoint source discharges from the 1500 dairies in its purview, and is developing a similar program for seven million acres of irrigated agriculture in the Delta watershed, there is still limited available data to indicate where nitrogen runoff is occurring and how its impacts can be controlled."[37]

This respondent further suggests:

> The California Department of Food and Agriculture maintains data on fertilizer sales by county, which can be used to provide an idea of the relative quantities of fertilizer compared with nonpoint source discharges by wastewater treatment plants…While EPA has no ability to regulate discharges from agriculture, improved reporting and monitoring can help pinpoint specific problem areas.[38]

SELENIUM

Twelve respondents answered questions on selenium, including environmental organizations (4), regulated dischargers (2), resource agencies (2), water agencies (2), a regulatory agency (1), and a local resident (1).

Key Points

- ⇨ Various interest groups see the development of wildlife and aquatic life criteria for selenium as an opportunity for addressing science and regulatory gaps, if based on new information on environmental processes in the estuary.
- ⇨ The ECoS3 estuary model and the Presser-Luoma biodynamic model are new tools for better understanding the fate, transport, and biotic uptake of selenium in the estuary.
- ⇨ Additional data may help to improve the modeling framework, develop selenium criteria, and better characterize existing and future risks to fish and wildlife.

35 San Luis Delta & Mendota Water Authority, State Water Contractors (EPA-R09-OW-2010-00 38.1)
36 US Fish and Wildlife Service (EPA-R09-OW-2010-0052.1)
37 Clean Water Action (EPA-R09-OW-2010-0044.1)
38 Clean Water Action (EPA-R09-OW-2010-0044.1)

⇨ Retiring drainage problem lands in the Western San Joaquin Valley is a widely supported key strategy to eliminate problems caused by selenium-laden drainage water.

1. **What, if any, additional information is available to better characterize selenium sources, loadings and impacts within the watershed of the Bay Delta Estuary?** (9 answers)

Several respondents address dietary exposure and toxicity in different species in various environments. They discuss these issues in connection with EPA's development of wildlife and aquatic life guidance criteria. One respondent, referring to remaining uncertainties in modeling and evaluating biotic uptake, comments: "there are still gaps in our knowledge of the key factors that affect the transfer and potential toxicity of selenium through food webs."[39] Several commenters cite the ongoing North San Francisco Bay Selenium Characterization Study as a source of new information that may help address some of these remaining uncertainties:

> Additional data are now being collected to provide better characterization of the relationship between riverine inputs of selenium and the processes in the North Bay that affect biotic uptake. This new information will be also used to fine-tune the model's calibration, which, in turn, will enhance the accuracy of the model's future predictions.[40]
>
> The new data collected in the Selenium Characterization Study provide the basis for a major reevaluation of selenium speciation in the bay after a gap of 10 years.[41]

Various interest groups view the development of new criteria as an opportunity to address scientific and regulatory limitations of the current water quality standards. Some consider the current standards as not sufficiently protective: "Nevertheless, a sizeable body of knowledge has been assembled in the past thirty years indicating that the current standard is insufficiently protective, but also demonstrating a way forward through the use of ecosystem scale models that link trophic levels and selenium biodynamics."[42] Others argue that the current standards overestimate the potential for adverse ecological effects. They expect this issue to be addressed by considering the new information on selenium speciation: "Selenium speciation is critical to the understanding of ecosystem impacts."[43]

Commenters also point to potential improvements to the estuary's selenium mass balance: "The Bay Delta ANPR relies on a study that drastically overstates the quantity of selenium likely to be transported into the Delta from agricultural drainage sources in the San Joaquin Basin and that also contains statements that characterize the likelihood of transport of selenium from that Basin as posing a major threat of increasing selenium contamination that would require additional intervention by US EPA. Such reliance and statements are not supported. There is an approved TMDL for selenium in the San Joaquin River and that along with current data should be used when estimating agricultural impacts from the San Joaquin River to the Delta."[44] Along the same lines, a respondent suggests to undertake efforts to improve the selenium mass balance for the Sacramento/San Joaquin Rivers to improve model inputs and assessments.

---

39 San Francisco Bay Regional Water Quality Control Board (EPA-R09-OW-2010-00 42.1)
40 San Francisco Bay Regional Water Quality Control Board (EPA-R09-OW-2010-00 42.1)
41 Western States Petroleum Association (EPA-R09-OW-2010-00 23.5)
42 The Bay Institute (EPA-R09-OW-2010-0040.4)
43 San Luis Delta & Mendota Water Authority, State Water Contractors (EPA-R09-OW-2010-00 38.1)
44 San Luis Delta & Mendota Water Authority, State Water Contractors (EPA-R09-OW-2010-00 38.1)

A representative of municipal dischargers suggests that based on recent data, the actual loading from Publicly Owned Treatment Works (POTWs) is likely half of that estimated in the *Preliminary Project Report* for a TMDL for San Francisco Bay:

> This report relies on effluent data from 1998 through 2007 to estimate loading from publicly owned treatment works (POTWs) at approximately 226 kilograms (kg) per year…A comparison of the calculations for most of the dischargers listed in Table 11 of the TMDL Report to those using the more recent data set is attached and shows that actual loading is likely half of that estimated.[45]

2. **What data, studies, and analytical techniques (for example, models) could be used to improve our understanding of the physical processes, including surface-groundwater interactions, controlling selenium mobilization and transport to and within the Bay Delta Estuary?** (3 answers)

Two respondents discuss the ECoS3 estuary model as a new tool for better understanding the fate, transport, and biotic uptake of selenium in the estuary. A regulatory agency representative describes the issue this way:

> As the ANPR notes, the Water Board has begun work on a TMDL project to address the selenium impairment listings of the northern segments of San Francisco Bay. The most current scientific evidence was used to develop the ECoS3 estuary model, which can successfully simulate selenium concentrations in the water column and sediments and track mobilization and transport of selenium through the North Bay. …
> Additional data are now being collected to provide better characterization of the relationship between riverine inputs of selenium and the processes in the North Bay that affect biotic uptake. This new information will be also used to fine-tune the model's calibration, which, in turn, will enhance the accuracy of the model's future predictions.[46]

The second commenter provides new ECoS3 simulation results that accurately simulate the long-term record of selenium in the clam *Corbula amurensis*: "Simple representations have been proposed for biological uptake, principally by assuming that particulate selenium is a ratio of the dissolved selenium (represented as a value of K_d…),"[47] remarks the respondent about shortcomings of previous analyses. "However, this approach does not capture the changing selenium speciation in the Bay and does not explain the variations in clam concentrations that have been observed over the last 15 years. Given this limitation, the simple K_d-based approach may not be able to project future clam concentrations, especially when there are changes in the hydrologic drivers, such as modifications in the flows through the Delta, or changes in the mix of Sacramento and San Joaquin River inflows."[48]

The commenter suggests that ECoS3 accounts for the various transformations and uptake processes applying to the multiple dissolved and particulate species of selenium. "The goal of this effort was to develop a linkage between sources, water column concentrations, and biota concentrations that represents the best current understanding of underlying processes."[49]

45 CASA, BACWA, CVCWA, Tri-TAC, SCAP (EPA-R09-OW-2010-0034.1)
46 San Francisco Bay Regional Water Quality Control Board (EPA-R09-OW-2010-00 42.1)
47 Western States Petroleum Association (EPA-R09-OW-2010-00 23.5)
48 Western States Petroleum Association (EPA-R09-OW-2010-00 23.5)
49 Western States Petroleum Association (EPA-R09-OW-2010-00 23.5)

As a first step, various existing data sources were used to characterize loads from all known point and non-point sources. Load estimates from the study are as follows: "Annual loadings from the Central Valley through the Delta are the largest source of selenium with high variability depending on total flow through the Delta. Loads in high flow years are estimated to be more than ten times higher than in low flow years. The average Delta load is estimated to be 3,962 kg/yr. Local tributaries draining both urban and non- urban areas, although contributing lower flows than the Sacramento and San Joaquin Rivers, have high selenium concentrations, and are also a large source of selenium during the wet months (estimated average load of 354-834 kg/yr). Refineries are estimated to contribute ~550 kg/yr to North San Francisco Bay."[50]

The consistency of simulated selenium concentrations in *C. amurensis* with long-term monitoring data collected by the U.S. Geological Survey (USGS) at the Carquinez Strait for the period of 1994-2010 was presented as the most compelling evidence that ECoS3 addresses the need to better explain selenium processes controlling selenium mobilization and transport to and within the Bay-Delta Estuary:

> Overall, the model is able to describe key features in the clam concentration behavior accurately. Changes from the dry season (high concentrations) to the wet season (low concentrations) in each annual cycle are explained by the riverine input of mineral-Se with lower concentrations and lower assimilation efficiency. Changes in clam selenium concentrations from one year to the next are influenced significantly by hydrology, with wet years (such as 2005 and 2006) resulting in lower clam concentrations. The ability to explain this temporal clam behavior also provides insight into future changes in the Bay, where flow modifications in the San Joaquin River or the Delta may result in riverine inputs that differ from historical, both in volume and in the amount of particulate selenium represented by the relative proportion of Sacramento and San Joaquin River flows.[51]
>
> Although more complex than a ratio-based approach, the added benefit of explaining mechanistically an important process of selenium uptake in the system, makes this an important tool in assessing future changes over the long term.[52]

A third respondent cites the Luoma-Presser model, a biodynamic model that integrates the chemical and the physiological factors that control how various animals from different parts of the foodweb bioaccumulate selenium:

> The Luoma and Presser selenium model being used by the EPA for developing site-specific criteria for the Estuary is of high quality and is flexible enough to be used in freshwater systems inland.[53]

3. **What data are needed to track selenium impacts in the Bay Delta ecosystem as currently configured, and to evaluate potential impacts of selenium under changed flow and transport conditions into and within the Delta?** (6 answers)

Respondents identify data needs for the modeling framework, the development of selenium criteria, and better characterization of existing and future risks to fish and wildlife. A representative of a regulated discharger association comments: "There is a critical need to develop a focused data

50 Western States Petroleum Association (EPA-R09-OW-2010-00 23.5)
51 Western States Petroleum Association (EPA-R09-OW-2010-00 23.5)
52 Western States Petroleum Association (EPA-R09-OW-2010-00 23.5)
53 US Fish and Wildlife Service (EPA-R09-OW-2010-0052.1)

collection effort to develop information: 1) to establish existing conditions in the Bay Delta with respect to the effects of selenium, 2) to serve as a basis for measuring change to the system, and 3) to gauge the effects of ecological forcing factors such as changes in food-web structure, flow conditions, and different sources and forms of selenium to the system."[54]

Several respondents identify specific data needs for the San Joaquin River system. One strongly urges "the development of a comprehensive monitoring program in the San Joaquin River, focusing on the reach between Mud Slough (GBP[55] discharge) and the confluence with the Merced River (which dilutes the GBP-discharged selenium)," for the reason that, "special focus is needed to monitor and address potential impacts on salmonids migrating through the San Joaquin River upstream of the Merced River confluence."[56]

This view is echoed by another commenter, who recommends, "juvenile salmonids be sampled in areas of the San Joaquin River at greatest risk to selenium exposure to assess the level of risk posed by selenium to salmonid species. Habitat use by juvenile salmonids in the San Joaquin River should also be monitored where risks are the greatest for selenium exposure to assess the level of risk posed by selenium to salmonid species."[57]

Along these lines, a respondent identifies a broader need for more systematic monitoring of biological indicators. "Biological indicators of selenium contamination are much better than weekly or monthly water samples that can mask short-term spikes and variations in selenium loads. In the words of the U.S. Fish and Wildlife Service, "Avian and Fish Production are two of the most sensitive endpoints for selenium."[58] The respondent also makes the following recommendation:

> USEPA should develop, propose, and implement avian and fish egg selenium criteria for the Bay-Delta ecosystem… USEPA should implement biological selenium monitoring programs for avian and fish eggs, as well as other species.[59]

According to the answers, additional data could also help improve understanding of processes and mass balance calculations and result in improved modeling capabilities. The representative of a federal resource agency recommends, "the collection of particulate selenium concentrations and other data to improve mass balance calculations that will be useful for the Luoma and Presser selenium model."[60] The respondent of a trade association representing regulated dischargers suggested, "support of a modeling framework that ties together these elements and can be tested against the data should be an important component of the overall monitoring strategy for the Bay."[61] And, with regards to specific data needs:

> These data needs include 1) Delta selenium concentrations, 2) *C. amurensis* selenium concentrations and abundance, 3) particulate selenium concentrations at the ocean boundary, 4) selenium concentrations in higher trophic levels, and 5) a sustained selenium modeling framework.[62]

54 Western States Petroleum Association (EPA-R09-OW-2010-00 23.5)
55 GBP = Grassland Bypass Project
56 The Bay Institute (EPA-R09-OW-2010-0040.4)
57 US Fish and Wildlife Service (EPA-R09-OW-2010-0052.1)
58 California Water Impact Network, California Sportfishing Protection Alliance, and AquAlliance (EPA-R09-OW-2010-0024.1)
59 California Water Impact Network, California Sportfishing Protection Alliance, and AquAlliance (EPA-R09-OW-2010-0024.1)
60 US Fish and Wildlife Service (EPA-R09-OW-2010-0052.1)
61 Western States Petroleum Association (EPA-R09-OW-2010-00 23.5)
62 Western States Petroleum Association (EPA-R09-OW-2010-00 23.5)

4. **Are there additional selenium control methods or programs that should be considered for reducing selenium inputs and impacts?** (7 responses)

Based on the answers, retirement of drainage problem lands in the Western San Joaquin valley is a widely supported key strategy to eliminate problems caused by selenium-laden drainage water. One respondent advocates for the approach as follows:

> The Bureau of Reclamation, in its San Luis Feature Re-evaluation EIS[63] economic analysis concluded that retirement of drainage problem lands in the San Luis Unit is the most cost effective solution. The Environmental Working Group has identified an additional $10 million/year in crop subsidies to those drainage problem lands in Westlands. USEPA should encourage retirement of drainage problem lands in the Western San Joaquin Valley as a means of reducing pollution, saving taxpayer funds and reducing water demand from the Delta.[64]

PESTICIDES

Eighteen respondents answered questions on pesticides, including regulated dischargers (5), resource and planning agencies (5), environmental organizations (2), regulatory agencies (2), water agencies (2), a commodity group (1), and a water user group (1).

Key Points

- ⇨ Of all pesticides, respondents consider pyrethroids the single-largest water quality concern.
- ⇨ Respondents want EPA to focus on efforts to keep pesticides from entering sensitive environments entirely rather than focusing on water quality criteria.
- ⇨ Effective solutions need to focus on the elimination of the pesticide uses and products that are likely to cause water quality problems.
- ⇨ Broad consensus exists that the most effective actions for EPA to address pesticide contamination would be a) continue to improve water quality protection through regulatory authority that exists in FIFRA, and b) implement and provide incentives for reducing pesticide use, runoff, and drift.
- ⇨ EPA's Common Effects Characterization Methodology initiative is considered the kingpin in EPA's efforts to regulate pesticide contamination in the estuary.
- ⇨ Several respondents doubt the utility of fish tissue concentrations in assessing exposure and effects of current use pesticides.

1. **What, if any, additional scientific information is available on (a) the effects of pesticides in stormwater discharges, or (b) the potential interactive effects of combinations of**

63 Environmental Impact Statement

64 California Water Impact Network, California Sportfishing Protection Alliance, and AquAlliance (EPA-R09-OW-2010-0024.1)

pesticides on aquatic resources in the Bay Delta Estuary? (8 answers)

Pyrethroid pesticides are a main topic in the answers, whereas most if not all of the cited information had already been considered in the preparation of the ANPR. "Urban stormwater discharges and wastewater treatment plants (WWTPs) are significant sources of pyrethroid pesticides to the Bay Delta Estuary"[65], answers a commenter in response to question (a). "A recent study by Weston and Lydy[66] demonstrates this point."[67]

Some respondents cite specific monitoring results for consideration. One regulated discharger group comments on toxicity caused by organophosphate pesticides: "SRWP[68] also found there were no substantial differences in the frequency of toxicity observed in the different types of waterbodies monitored in 2006 and 2007 (mainstem river, major tributaries, agricultural drainages, and urban creeks)."[69] The results are from toxicity test with *Ceriodaphnia dubia*, a species susceptible to organophosphate pesticides, but not as susceptible to pyrethroids. That said, several other respondents cite information that supports using *Hyalella azteca* in toxicity monitoring, a resident species that is more susceptible to pyrethroids, instead of or in addition to *Ceriodaphnia dubia*.

Several respondents cite recent information to highlight what they perceive as shortcomings in the ANPR's discussion of pesticide effects. As a water user group points out, in the context of toxicity testing: "These data do not take into account an even lower threshold of toxicity to protect against sublethal effects (e.g., lower than acute toxicity values by a factor of 10) and, for pyrethroids, higher toxicity at lower temperatures (an additional factor of 3), such as those found in the Delta and its tributaries during the winter storm season when pesticide runoff is greatest and sensitive life stages are most vulnerable to contaminant exposure."[70]

Finally, others cite recent studies by the National Marine Fisheries Service that should be consulted to evaluate possible impacts on salmonids. A federal resource manager puts it this way: "The recent biological opinions from NMFS on pesticides provide the most detailed, high quality, and to-date assessment of pesticide risks to salmonids."[71]

2. **What, if any, actions should EPA take under its authority to improve the effectiveness of regulating pesticide contamination of the Bay Delta Estuary watershed?** (15 answers)

There is widespread support for EPA's Common Effects Characterization Methodology initiative, which is viewed as the most important action in EPA's efforts to regulate pesticide contamination in the estuary. Says a regional resource management and planning coordinator: "The UP3 Project[72] finds that the root of pesticide-related surface water toxicity issues, and the problem that most needs a solution, is a regulatory gap: pesticides may be registered through USEPA's Office of Pesticide Programs (OPP) under the Federal Fungicide, Insecticide, and Rodenticide Act (FIFRA) that will cause water quality impairment and exceedances enforceable by USEPA's Office of Water (OW) under the Clean Water Act (CWA)."[73]

65 Westlands Water District (EPA-R09-OW-2010-0037.1)
66 See ANPR note 205.
67 Westlands Water District (EPA-R09-OW-2010-0037.1)
68 Sacramento River Watershed Program.
69 Sacramento Valley Water Quality Coalition (EPA-R09-OW-2010-0032.1)
70 Coalition for a Sustainable Delta (EPA-R09-OW-2010-0043.1)
71 US Fish and Wildlife Service (EPA-R09-OW-2010-0052.1)
72 Urban Pesticide Pollution Prevention (UP3) Project
73 San Francisco Estuary Partnership/Association of Bay Area Governments (EPA-R09-OW-2010-0041.1)

Most of the other respondents agree with this assessment, as the following comments illustrate:

> Require internal coordination efforts between FIFRA and Office of Water.[74]
>
> Regardless of any other action EPA takes to improve the water quality for aquatic species in the Estuary, long-term reduction in pesticide-related impairment cannot be achieved without improving EPA's pesticide approval process. In November 2008, EPA's Office of Pesticide Programs (OPP) and Office of Water (OW) introduced a joint project to integrate EPA's aquatic effects characterization methods and provide a common basis to achieve the water quality protection goals of the Clean Water Act (CWA) and the Federal Insecticide Fungicide and Rodenticide Act (FIFRA). This is a most welcome and important endeavor, because pesticides currently being used in accordance with approved label instructions are causing and/or contributing to toxicity in waters of the U.S. and State.... Recent updates on the EPA OW/OPP project have indicated that the common methodology being drafted by the two offices is likely to result in a pesticide registration process that more effectively considers aquatic impacts. We strongly encourage regional EPA staff to participate in and support this project, because we view it as the kingpin in EPA's efforts to regulate pesticide contamination of the Bay Delta Estuary.[75]
>
> Despite the water quality problems...that exist due to pesticide uses registered under FIFRA programs, staff believe that pesticide use regulation under FIFRA is improving its protection of water quality, and should be a key piece of the solution to the pesticide problems in the Bay-Delta. Achieving this solution will require coordination between Clean Water Act programs and FIFRA pesticide use regulatory programs.[76]
>
> Coordination between EPA's Offices of Pesticide Programs, Water, and Wastewater Management in reviewing pesticide data needs is essential to Clean Water Act implementation; it also provides an appropriate method of meeting FIFRA's goal of preventing unreasonable adverse impacts from pesticide use.[77]

Based on the OPP-OW "harmonization"[78] effort and other related initiatives, respondents hold expectations that the regulatory gap will be closed:

> In our experience, the greatest success in controlling pesticides discharges can be achieved when both pesticide use regulation (based on FIFRA and the California Food and Agriculture Code) and water quality-based regulations (based on the Clean Water Act and California's Porter-Cologne Water Quality Control Act) are implemented in tandem to protect water quality. An example of these programs working in tandem is the recently documented success in reducing diazinon runoff in the Sacramento and Feather Rivers, which involved Clean Water Act (Nonpoint Source and TMDL) programs, changes in the diazinon label requirements under FIFRA, and the California Department of Pesticide Regulation (DPR)'s establishment and implementation of dormant spray regulations.... Staff hopes there is now a fundamental consensus that attaining the water quality standards established under the Clean Water Act should be a goal of USEPA's OPP in regulation of pesticide use,

74 Sacramento Regional County Sanitation District (EPA-R09-OW-2010-0022.1)
75 San Francisco Bay Regional Water Quality Control Board (EPA-R09-OW-2010-00 42.1)
76 Central Valley Regional Water Quality Control Board (EPA-R09-OW-2010-00 21.1)
77 CASA, BACWA, CVCWA, Tri-TAC, SCAP (EPA-R09-OW-2010-0034.1)
78 San Francisco Estuary Partnership/Association of Bay Area Governments (EPA-R09-OW-2010-0041.1)

> and that non-attainment of water quality standards should be considered to be an unreasonable adverse effect under FIFRA. There are a number of ongoing efforts, which staff applauds, where pesticide use regulation under both FIFRA and the California Food and Agriculture Code are being closely coordinated with water quality regulation and Clean Water Act programs.[79]
>
> The UP3 Project has worked to communicate this gap to regulators. The UP3 Project has prepared comments for regulatory review periods for current pesticides of concern to water quality, through a resource-intensive pattern of reviewing work plans and communicating water quality concerns for each individual regulatory review. The UP3 Project has had successes in securing changes to label directions or allowed use patterns through these methods, and in general we believe that state and federal regulators are much more aware of water quality issues related to pesticide toxicity as a result of the decade of effort by the UPC.[80]

Several respondents, though, share the view that the practical and cost effective means of controlling pesticide discharge is for the federal government to use its authorities under FIFRA to regulate pesticide sales and use. A respondent representing regulated dischargers argues that, "POTWs have limited practical ability to keep residents and small businesses from discharging ordinary consumer products, like pyrethroids, to their indoor drains. For these reasons, attempts to address pesticide discharges through Clean Water Act-based regulation of POTWs effluent and biosolids will not lead to water quality improvement but will unfairly burden local wastewater agencies."[81]

Some point to the fact that EPA has existing authorities under FIFRA that, they argue, could be used more efficiently and effectively to protect water quality in the Bay Delta. A federal resource manager issues the following recommendations:

> Seek to amend the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) to require registrants to collect sufficient information to generate water quality criteria as part of the FIFRA registration or re-registration process in order to streamline establishment of numeric water quality criteria.... Require registrants to develop detection methodologies for all new and existing products at environmentally realistic concentrations before the products are registered or re-registered under FIFRA in order to improve the effectiveness of controlling pesticide contaminants and protect designated beneficial uses.... Require generation of toxicity data to determine if there are additive or synergistic interactions as part of the registration and re-registration processes under FIFRA. Put this on a fast track for the known pesticide contaminants in the Bay-Delta estuary through funding of independently conducted studies, if necessary. ... Seek to amend FIFRA to add testing requirements to the registration and re-registration processes of FIFRA that match the longer exposure times to pesticides observed in the Bay Delta Estuary in order to produce accurate effects information.[82]

The representative of a regulated discharger association is equally forthright in asserting that pesticide regulation under FIFRA "can protect Delta water quality:"[83]

79 Central Valley Regional Water Quality Control Board (EPA-R09-OW-2010-00 21.1)
80 San Francisco Estuary Partnership/Association of Bay Area Governments (EPA-R09-OW-2010-0041.1)
81 CASA, BACWA, CVCWA, Tri-TAC, SCAP (EPA-R09-OW-2010-0034.1)
82 National Oceanic and Atmospheric Administration (EPA-R09-OW-2010-0050.1)
83 California Stormwater Quality Association (EPA-R09-OW-2010-0045.1)

> Both DPR and U.S. EPA Office of Pesticide Programs (OPP) have convinced us that they have the regulatory authority necessary to protect surface waters from pesticides…. U.S. EPA Region 9 should support OPP's and DPR's actions to use their pesticide regulatory authorities to protect the Delta and all other surface waters. …Since the scope of pesticide-related water quality challenges in the Delta is not fully understood, U.S. EPA Region 9 can also provide information and resources to collaborate with other agencies (e.g., OPP, DPR, USGS) toward monitoring the highest priority pesticides, and toward providing the type and quality of information that pesticide regulators need for regulatory action.[84]

Another regulated discharger association makes equally specific recommendations for using existing FIFRA authorities to protect Bay Delta water quality:

> EPA should also update and revise data requirements for the registration and registration review of pesticides under FIFRA….EPA should also evaluate potential impacts from synergists and multiple active ingredient pesticide formulations during pesticide registration and registration review….When potential water quality impacts are identified during registration or registration review for a pesticide, EPA should implement adequate risk management strategies.... EPA has already taken important steps towards protecting water quality through its various registration processes; however, EPA can further integrate urban water quality protection more effectively into its pesticide review programs.[85]

Some others, however, would welcome further action by EPA under both CWA and FIFRA. "The ANPR asks whether EPA should take further action under the Clean Water Act to control the discharges of pesticides to the Bay Delta Estuary," commented a spokesperson for water agencies, "With respect to pyrethroids, the answer to these questions is unequivocally yes, consistent with and cognizant of the principles of federalism…. EPA should also take action under FIFRA to supplement its efforts to control stormwater contributions of pyrethroids."[86]

3. **How can the process for establishing numeric water quality criteria be streamlined while maintaining technical integrity?** (4 answers)

Regarding the process for establishing numeric water quality criteria, the answers circle back to points made regarding the harmonization of pesticide harmonization under FIFRA and CWA: "In addition to continuing its efforts to harmoniz[e] the scientific underpinnings of water quality protections under FIFRA and CWA, EPA Office of Pesticide Programs should develop data requirements to be imposed on pesticide registrants for pesticide registration, registration review, and related regulatory process under FIFRA that are consistent with the data requirements for development [of] WQCs.,"[87] comments a local government official. "This will not only streamline WQC development, but will provide better data for making pesticide registration decisions protect water quality to levels consistent with water quality standards."[88]

All four answers raise fundamental concerns over EPA's focus on water quality criteria. "It would be better not to focus on criteria but rather implement and provide incentives for reducing pesticide

84 California Stormwater Quality Association (EPA-R09-OW-2010-0045.1)
85 CASA, BACWA, CVCWA, Tri-TAC, SCAP (EPA-R09-OW-2010-0034.1)
86 Westlands Water District (EPA-R09-OW-2010-0037.1)
87 County of Sacramento (EPA-R09-OW-2010-0020.1)
88 County of Sacramento (EPA-R09-OW-2010-0020.1)

use, runoff and drift,"[89] suggests one participant. "The potential combinations of registered pesticides and chemicals, the exposure potential and ultimate toxicities are clearly too large to effectively address. We believe the best way to resolve this concern is through efforts to keep pollutants from entering sensitive environments entirely. We recommend EPA evaluate its registration process, education efforts, regulatory avenues and best management practices to determine which would effectively reduce or eliminate non-target pesticide toxicity."[90] All answers oppose changes to established procedures for developing water quality criteria and reiterate key points made in response to General Contaminants Question 2, regarding the need to shift focus from end-of-pipe regulation to source control:

> As detailed in the response to question 2 above, the water quality impacts of pesticides should be properly evaluated and mitigated during EPA's registration processes thus preventing water quality impacts and making mitigation under the Clean Water Act minimal or unnecessary.[91]
>
> EPA should be very cautious about streamlining how to establish numeric criteria as the streamlining itself could threaten the technical integrity of the criteria development process, especially where little data exists. Any process that relies on large safety factors to account for a paucity of supporting data should be avoided.[92]
>
> We are in favor of the continued use of EPA guidelines and methods for the development of aquatic life-based criteria. EPA has these well-established procedures in place to develop water quality criteria for aquatic life and drinking water standards. EPA should not circumvent these procedures in developing regulatory criteria for pesticides.[93]

Comments also reflect frustration over the existing regulatory gap and the resulting costs to dischargers, which are perceived to be the result of water quality protection that relies heavily on CWA regulatory tools to control discharges that could be prevented in the first place by more effectively using FIFRA regulatory tools:

> Over the years, various pesticides have been implicated and identified as the source of water quality impairments. With protective aquatic life water quality criteria established for only a few of these compounds, the majority of these pesticide impairments were identified through regulatory-mandated acute and chronic toxicity testing programs. The costs to POTWs associated with these impairments have exceeded millions of dollars.[94]

4. **What are the benefits and constraints of using fish tissue in place of, or in addition to, water column concentrations when establishing water quality criteria for pesticides?** (4 answers)

In similar fashion, respondents are skeptical about the use of fish tissue concentrations when establishing water quality criteria. Two respondents point to the paucity of fish tissue concentration data that would likely limit this tool:

89 US Fish and Wildlife Service (EPA-R09-OW-2010-0052.1)
90 US Fish and Wildlife Service (EPA-R09-OW-2010-0052.1)
91 CASA, BACWA, CVCWA, Tri-TAC, SCAP (EPA-R09-OW-2010-0034.1)
92 Sacramento Regional County Sanitation District (EPA-R09-OW-2010-0022.1)
93 CASA, BACWA, CVCWA, Tri-TAC, SCAP (EPA-R09-OW-2010-0034.1)
94 CASA, BACWA, CVCWA, Tri-TAC, SCAP (EPA-R09-OW-2010-0034.1)

> There is a wealth of information available describing effects to various aquatic organisms based on surface water concentrations, while only limited data are available describing effect concentrations in tissues, and such concentrations are organism and tissue specific. Therefore, it is most useful to have water quality (and sediment) data for assessing the potential for adverse effect to biota.[95]

Commenters also question the relevance of fish tissue concentrations in assessing exposure and effects of current use pesticides. A federal resource manager comments: "This question is less relevant for modern pesticides which do not tend to accumulate in fish tissues."[96] All commenters argue against a focus on criteria and reiterated the need to shift focus to the registration process. In the words of a wastewater source control planner, "To gain a broad picture of the effects of pesticides on ecosystem health, all pathways of exposure (water column, sediment and biota) should be assessed through the registration and registration review under FIFRA."[97]

5. **Are there testing protocols that would effectively and efficiently identify synergistic toxic effects in the Bay Delta Estuary?** (3 answers)

Commenters again point to the need to focus on source control and the registration process. "EPA should adopt policies and regulations to establish data requirements for pesticide regulatory activities under FIFRA that are coordinated with water quality monitoring activities,"[98] comments a local government spokesperson. "For instance, comparable methods should be developed for use in pesticide registration and registration reviews, environmental monitoring, and biomarkers."[99]

The same commenter points to shortcomings in existing testing protocols. "EPA should recognize that currently available testing protocols are likely to be inadequate for identifying synergistic effects in the estuary."[100]

And with regard to the best approach: "In coordination with the Office of Pesticide Program's 21st Century Toxicology initiative, EPA Region 9 and the Office of Water should support development of modern toxicological methods for pesticides that can be used to tease out synergistic effects."[101]

The respondent describes the expected outcome as: "Coordination of these methods, and establishment of appropriate data requirements, will help not only to identify the cause of environmental problems, but also to better predict, and prevent or mitigate problems before chemicals are allowed to be released to the environment."[102]

Another respondent suggests improving toxicity testing protocols by better accounting for synergistic effects:

> Performing toxicity testing with ambient waters directly tests for synergistic toxic effects in the Bay Delta Estuary for the selected test organisms. Ambient waters contain mixtures of chemicals at environmentally relevant concentrations. Therefore, the results of toxicity tests provide at least a snapshot of synergistic or additive effects in the samples taken.[103]

95 Sacramento Regional County Sanitation District (EPA-R09-OW-2010-0022.1)
96 US Fish and Wildlife Service (EPA-R09-OW-2010-0052.1)
97 Sacramento Regional County Sanitation District (EPA-R09-OW-2010-0022.1)
98 County of Sacramento (EPA-R09-OW-2010-0020.1)
99 County of Sacramento (EPA-R09-OW-2010-0020.1)
100 County of Sacramento (EPA-R09-OW-2010-0020.1)
101 County of Sacramento (EPA-R09-OW-2010-0020.1)
102 County of Sacramento (EPA-R09-OW-2010-0020.1)
103 Sacramento Regional County Sanitation District (EPA-R09-OW-2010-0022.1)

The uncertainties related to the lack of realistic environmental exposure in laboratory-based toxicity testing could be addressed by conducting *in situ* toxicity testing in the Delta. This approach balances the controls of standard laboratory testing with environmentally realistic field exposures where the organisms are exposed to natural diurnal changes in temperature, light, and flow through water quality variations in the various site media (i.e., surface water, sediment- water interface, surficial sediment, or pore water). These *in situ* exposure approaches provide unique assessment information that is complementary to traditional laboratory-based toxicity testing and reduce the uncertainty of extrapolating from the laboratory to field. Native test organisms and standard method test organisms have been used successfully with *in situ* exposure methods to assess the potential for adverse effects to species of interest.[104]

The relative toxicity from multiple stressors in ambient surface water or sediment samples can, some cases, be determined using toxicity identification evaluation methods (EPA 1992, 1993a, 1993b, 2007). Toxicity identified during standard toxicity tests can be fractionated and then reconstructed for various toxicants. Novel methods need to be employed for some contaminant classes such as pyrethroids (Wheelock et al. 2004; Amweg and Weston 2007; Weston and Amweg 2007) in addition to the general tools provided in the EPA Guidance (EPA 1992, 1993a, 1993b).[105]

6. **What, if any, specific combinations of contaminants are of particular concern in the Bay Delta Estuary?** (3 responses)

Two respondents reiterate key points made in addressing other questions. For example, one of the respondents representing regulated municipal entities cited under question 3 reiterated one of the main points made there. “As mentioned above, the results of tests performed on ambient waters already provide an integrated account of any synergistic or additional effects.”[106]

This suggestion comes from a water agency representative: ”Given the recent research results demonstrating the effects on fish olfactory and lateral line function of short term exposures to low levels of copper and other contaminants, US EPA should conduct, or fund, additional investigations on the effect of metals and other contaminants on Delta pelagic and anadromous fish olfactory function.”[107]

7. **Should EPA and our state partners move away from evaluating isolated aquatic species for one or two pollutants, and towards evaluations of water conditions more representative of the actual aquatic conditions in the Bay Delta Estuary? How might this be done?** (3 responses)

Respondents reiterate key points made in answers to previous questions. From this question forward, with some exceptions, answers are few and become increasingly standardized. This may be related to the fact that questions 7-11 are variations on similar themes, address regulatory details that are not relevant to all interests, and that the basic concerns and ideas of commenters apply to several or all of them. For example, with regard to questions 6 and 7, one respondent’s

104 Sacramento Regional County Sanitation District (EPA-R09-OW-2010-0022.1)
105 Sacramento Regional County Sanitation District (EPA-R09-OW-2010-0022.1)
106 Sacramento Regional County Sanitation District (EPA-R09-OW-2010-0022.1)
107 San Luis Delta & Mendota Water Authority, State Water Contractors (EPA-R09-OW-2010-00 38.1)

"answer to these two questions is related."[108]

A respondent bases the following call for more integrated health assessments on the need for capturing the full effect of contaminant mixtures:

> While there is certainly value in conducting species' sensitivity analyses on individual pollutants, this needs to be supplemented with *in situ* analyses of species' health using biomarkers and other sublethal indications of contaminant exposure and effect. Aquatic organisms are exposed to contaminant mixtures, often at undetectable levels of each constituent, for their entire life and over multiple generations. Grab samples do not capture the variation of this mixture that can occur at hourly, daily, and seasonal time scales. In addition, short duration (e.g. 7-day) toxicity tests do not capture life cycle type effects on a population.[109]
>
> We encourage EPA to fund such an integrated and comprehensive investigation.[110]

Another respondent argues that current laboratory testing protocols could induce testing artifacts:

> Performing three-species chronic toxicity testing on upstream water, downstream water, and effluent accounts for any synergistic or additive toxicity resulting from combined contributions of contaminants. Such testing accounts for multiple contaminants, at environmentally relevant concentrations. The results of such testing near the SRCSD effluent discharge has helped to address concerns regarding the potential effects of Sacramento River water being discharged into the Bay Delta Estuary.[111]
>
> As commented previously, the uncertainties related to the lack of realistic environmental exposure in laboratory-based toxicity testing could be addressed by conducting *in situ* testing in the Delta. This approach balances the controls of standard laboratory testing with environmentally realistic field exposures where the organisms are exposed to natural diurnal changes in temperature, light, and flow through water quality variations in the various site media (i.e., surface water, sediment-water interface, surficial sediment, or pore water).[112]

8. **What new or revised effluent limitations, monitoring requirements or other permit requirements could be included in NPDES permits for discharges of pesticides from MS4s in the Bay Delta Estuary in order to meet the regulatory standard of reducing discharges to the maximum extent practicable? What information is necessary to determine permit requirements, such as identifying effluent limits that can effectively reduce ambient contaminant concentrations and restore designated uses? Please provide any available information on water quality benefits that may result from such requirements** (4 responses)

The respondents agree that additional requirements in MS4 permits would not be necessary or productive and provide three key arguments in support of their view: the most effective action for EPA to address pesticide contamination is to continue to improve water quality protection through

108 San Luis Delta & Mendota Water Authority, State Water Contractors (EPA-R09-OW-2010-00 38.1)
109 San Luis Delta & Mendota Water Authority, State Water Contractors (EPA-R09-OW-2010-00 38.1)
110 San Luis Delta & Mendota Water Authority, State Water Contractors (EPA-R09-OW-2010-00 38.1)
111 Sacramento Regional County Sanitation District (EPA-R09-OW-2010-0022.1)
112 Sacramento Regional County Sanitation District (EPA-R09-OW-2010-0022.1)

regulatory authority that exists in FIFRA; pesticide regulation under FIFRA offers a practical and cost-effective approach to addressing problems associated with pesticides that flow to the Delta in urban runoff; and EPA should rather implement and provide incentives for reducing pesticide use, runoff, and drift.

9. **What new or revised effluent limitations, monitoring requirements or other permit requirements could be included in NPDES permits for stormwater discharges associated with construction activity and/or stormwater discharges associated with industrial activity to address pesticides? What information is necessary to determine permit requirements, such as identifying effluent limits that can effectively reduce ambient contaminant concentrations and restore designated uses? Please provide any available information on water quality benefits that may result from such requirements** (3 responses)

Similar to previous responses, commenters do not support additional requirements on NPDES construction permittees and called for improvements in FIFRA water quality protections. One respondent provides the following answer to Questions 8-11: "Pesticide regulation offers a practical and cost-effective approach to addressing problems associated with pesticides that flow to the Delta in urban runoff. The alternative contemplated in the ANPR—expansion of NPDES permitting for pesticides in urban runoff—would be ineffective, costly, and counterproductive."[113] Commenters also provide specific suggestions for improving FIFRA regulations and coordinating these with NPDES construction permit monitoring and Best Management Practices:

> EPA should continue to require that pesticides labeled for pre-construction termiticides include restrictions and requirements to reduce the likelihood of pesticide discharge in stormwater runoff. Such requirements have been established by EPA, largely in response to requests from CASQA and individual MS4 permittees (including the County) for cypermethrin, bifenthrin, permethrin and other pyrethroids that have been implicated in water quality problems in the estuary.[114]
>
> These pesticide label requirements should be supported by parallel BMP and monitoring requirements in NPDES construction permits.[115]

Commenters also agree that, "Pesticide restrictions in NDPES industrial permits does not seem an efficient or necessary means to address pesticide applications at industrial facilities."[116] The respondents expect pesticide use restrictions under FIFRA and surface water protection regulations developed by the California Department of Pesticide Regulation to fully address pesticide problems in stormwater runoff.

10. **Should EPA use its residual designation authority at 40 C.F.R. 122.35 to designate currently unregulated small MS4s to ensure that municipalities have programs in place to control the discharge of pesticides in stormwater to the maximum extent practicable? What information is necessary to determine permit requirements, such as identifying effluent limits that can effectively reduce ambient contaminant concentrations and restore designated uses? Please provide any available information on water quality benefits that may result from such requirements** (4 answers)

---

113 California Stormwater Quality Association (EPA-R09-OW-2010-0045.1)
114 County of Sacramento (EPA-R09-OW-2010-0020.1)
115 County of Sacramento (EPA-R09-OW-2010-0020.1)
116 County of Sacramento (EPA-R09-OW-2010-0020.1)

This question receives the same resistance as previous ones: "Municipalities do not have the authorities necessary to prevent toxicity in their effluents: they cannot control pesticide labels—and in most states (including California) they cannot regulate pesticide users and cannot determine which pesticides can be sold in their cities. Since most urban dischargers do not have the ability to control pesticides, expansion of urban stormwater discharge permits would be ineffective toward addressing pesticide problems in the Delta."[117] Or: "Without improvement in FIFRA water quality protections, additional requirements on NPDES permittees to address pesticide impacts are likely to be ineffective."[118]

A federal resource manager, on the other hand, suggests to extend NPDES permitting to currently unregulated small MS4s and to include requirements for stormwater management plans and low impact development strategies:

> Require that all small, currently unregulated MS4s obtain National Pollutant Discharge Elimination System (NPDES) stormwater permit coverage and are required to utilize Standard Urban Stormwater Management Plan (SUSMP)/low-impact development (LID) strategies, including best management practice (BMP) sizing criteria, to minimize the inputs of pesticides and other contaminants to the Bay Delta Estuary. NMFS believes that many of the development companies in the State of California are well versed in the SUSMP/LID requirements from their projects in already regulated areas and that completing coverage across the state should not be overly burdensome.... Ensure that stormwater permits require periodic testing of discharges from existing urban developments and that toxicity detections trigger a toxicity identification evaluation (TIE) followed by an appropriate series of actions meant to prevent further toxic discharges. Ensure that stormwater permits require periodic analysis of individual contaminants and receiving waters to determine the effects of discharges on water quality standards in a waterbody.[119]

One of EPA's actions would then be to ensure the implementation of stormwater regulation and management: "Audit the Regional Water Quality Control Boards and the State Water Resources Control Board to determine if strict enforcement and reporting of the stormwater best management practices (BMP) requirements for redevelopment, as defined under the current and future stormwater NPDES permits, is taking place as required."[120] And as necessary, "Take corrective action against permittees who are not implementing the provisions properly."[121]

11. **Should EPA use its residual designation authority at 40 C.F.R. 122.26(a)(9)(i)(C)-(D) to designate currently unregulated stormwater discharges that contribute pesticides to surface waters? What information is necessary to determine permit requirements, such as identifying effluent limits that can effectively reduce ambient contaminant concentrations and restore designated uses? Please provide any available information on water quality benefits that may result from such requirements** (3 answers)

The answers repeat points made previously and are echoed in a general comment from a regulatory agency: "Municipalities, however, do not have control of what pesticides are sold or used, nor do they have resources to regulate pesticide applications."[122]

117 California Stormwater Quality Association (EPA-R09-OW-2010-0045.1)
118 County of Sacramento (EPA-R09-OW-2010-0020.1)
119 National Oceanic and Atmospheric Administration (EPA-R09-OW-2010-0050.1)
120 National Oceanic and Atmospheric Administration (EPA-R09-OW-2010-0050.1)
121 National Oceanic and Atmospheric Administration (EPA-R09-OW-2010-0050.1)
122 Central Valley Regional Water Quality Control Board (EPA-R09-OW-2010-00 21.1)

Respondents identify as a core issue the application by residents and professionals of USEPA-registered pesticides causing toxicity in discharges for which municipalities are ultimately held responsible. "Treatment of municipal stormwater to meet the low levels of pesticides necessary to prevent toxicity and achieve compliance with water quality standards would likely not be feasible."[123]

Education, low impact development, and permits requiring the implementation management practices to reduce toxic levels of pesticides in discharges are some of the feasible control efforts that were identified. That said, there are "likely limitations to how much pesticide reduction municipalities can feasibly achieve."[124]

The general consensus emerging from these answers is that effective solutions need to focus on the elimination of the pesticide uses and products that are likely to cause water quality problems.

CONTAMINANTS OF EMERGING CONCERN

Seven respondents answered questions on contaminants of emerging concern (CECs), including regulated dischargers (3), an environmental organization (1), a local resident (1), a resource management agency (1), and water agencies (1).

Key Points

- ⇨ The San Francisco Bay RMP currently prepares a CEC synthesis focused on San Francisco Bay.
- ⇨ CECs can enter the aquatic environment from a variety of sources, including municipal and industrial wastewater systems, urban stormwater, confined animal feeding operations, and agricultural runoff.
- ⇨ Respondents expect EPA to play a lead role in developing monitoring methods and screening processes, and coordinating regulatory monitoring requirements.
- ⇨ Respondents want EPA to provide leadership in source reduction for CECs through its authority to regulate the use of chemicals in products or processes.

1. **What, if any, additional information is available regarding the effects of CECs on aquatic resources in the Bay Delta Estuary?** (4 responses)

Respondents identify the following additional information resources: SETAC expert groups such as the Pharmaceutical Advisory Group and Nanotechnology Advisory Group; recent findings indicating exposure by Delta fish to endocrine disrupting chemicals (Brander and Cherr 2008, Connon et al 2010, Riordan and Adam 2008, Sommer 2008); the workshop report *Managing Contaminants of Emerging Concern in California*; and a CEC synthesis report being prepared by the San Francisco Bay RMP and expected to be available in the summer of 2012.

2. **What, if any, specific information exists to identify the sources and nature of discharges of CECs into the Bay Delta Estuary?** (5 responses)

123 Central Valley Regional Water Quality Control Board (EPA-R09-OW-2010-00 21.1)
124 Central Valley Regional Water Quality Control Board (EPA-R09-OW-2010-00 21.1)

Three respondents focus on CECs in discharges from municipal wastewater treatment systems. That said, one respondent replies: "We agree with the statement in the ANPR that CECs can be introduced into the aquatic environment through a variety of sources, including not only municipal wastewater systems but also industrial wastewater systems, urban stormwater, animal husbandry operations, and agricultural runoff. To be effective, efforts to address CECs must consider all of these sources, not just POTWs."[125] The respondents cite several studies, concluding that wastewater discharges are a likely source of a number of compounds that have been detected in the Delta downstream of urban centers. These compounds include caffeine, numerous pharmaceuticals, industrial chemicals, and fire retardants.

3. **What, if any, monitoring mechanisms or methodologies are available to assist in identifying CECs?** (5 responses)

Commenters endorse EPA's role in developing monitoring methods and screening processes, and coordinating regulatory monitoring requirements: "We encourage EPA to improve CEC analytical techniques..."[126] one commenter advises. Another "recommends that EPA establish coordinated product screening and environmental monitoring requirements for producers of chemicals that are potentially CECs that are designed to identify and prevent environmental impacts caused by their products."[127]

The spokesperson of several discharger associations suggested special studies, such as those conducted by the San Francisco Bay and Southern Bight RMPs, as a useful approach for characterizing sources and impacts of CECs:

> Additionally, our associations believe that the most useful approaches to identify the sources, fate, transport and effects of CECs in the environment is through special studies, rather than by a traditional regulatory approach or via routine compliance monitoring programs typically used for conventional and priority pollutants. The state of the science is not yet sufficiently developed to set regulatory standards, and therefore it is premature to require routine monitoring for many, if not most, CECs. Instead, special studies designed to answer particular questions related to the sources, fate, transport and effects of various CECs (or classes of CECs) are part of the important foundational work necessary to determine which compounds are of greatest concern and how best to address them. Much work in this area is already being undertaken by academic experts and applied research institutions such as the Southern California Coastal Water Research Project (SCCWRP) or the San Francisco Estuary Institute (SFEI), and they are well-positioned to assist in this role.[128]

Another respondent points to a risk-based monitoring strategy, as developed for recycled waters, as a model: "A State Water Board's expert panel supports a risk-based approach for evaluating the potential for adverse effects from CECs in their "Monitoring Strategies for Chemicals of Emerging Concern (CECs) in Recycled Water." This approach recommends monitoring (i.e., measured environmental concentration or MEC) and interpreting these monitoring data through chemical specific comparisons of concentrations known to cause adverse effects (i.e., monitor triggering level or MTL)."[129]

125 CASA, BACWA, CVCWA, Tri-TAC, SCAP (EPA-R09-OW-2010-0034.1)
126 CASA, BACWA, CVCWA, Tri-TAC, SCAP (EPA-R09-OW-2010-0034.1)
127 County of Sacramento (EPA-R09-OW-2010-0020.1)
128 CASA, BACWA, CVCWA, Tri-TAC, SCAP (EPA-R09-OW-2010-0034.1)
129 Sacramento Regional County Sanitation District (EPA-R09-OW-2010-0022.1)

4. **What, if any, methods are most effective to minimize introduction of CECs into the Bay Delta Estuary?** (6 responses)

Four commenters want EPA to assume a stronger role in addressing problems with CECs at their source. One respondent stated: "The area in which EPA can make the biggest difference in minimizing introduction of CECs into the environment is by providing leadership in source reduction for CECs."[130]

One of several identified problems is stormwater authorities' limited ability to control pollution sources. As one respondent states, "EPA must bring to bear other avenues of environmental protection, including chemical policy reforms and regulations to actively reduce the use of toxic, bioaccumulative, and persistent chemicals and promote environmentally sound alternatives."[131]

Issues brought forth are the technical challenges in removing the usually low concentrations of CECs from wastewater and stormwater and the associated cost. Respondents consider pollution control strategies for discharges technically questionable and financially unsustainable. They also point out that the Water Boards and local agencies, unlike EPA, do not have the authority to regulate the use of chemicals in products or processes. One commenter recommends "that EPA establish coordinated product screening and environmental monitoring requirements for producers of chemicals that are potentially CECs that are designed to identify and prevent environmental impacts caused by their products."[132]

According to one comment, the most effective treatment process for removing trace concentrations of pharmaceuticals and personal care products and other endocrine disrupting compounds would be a multiple barrier, treatment train approach that combines various advanced processes (e.g., reverse osmosis, advanced oxidation processes, ozonation, activated carbon). Costs to implement this treatment technology are expected to be exorbitant.

PROTECTING ESTUARINE HABITAT, FISH MIGRATION CORRIDORS AND WETLANDS

Comments were requested on three topics related to aquatic habitat:

- Estuarine habitat
- Fish migration corridors
- Wetlands

130 CASA, BACWA, CVCWA, Tri-TAC, SCAP (EPA-R09-OW-2010-0034.1)
131 Clean Water Action (EPA-R09-OW-2010-0044.1)
132 County of Sacramento (EPA-R09-OW-2010-0020.1)

ESTUARINE HABITAT

Five respondents answered questions on estuarine habitat, including environmental organizations (2), a resource management agency (1), water agencies (1), and a water user group.

Key Points

- ⇨ There are two distinct views about changing the location of the low salinity zone to achieve ecosystem benefits. One view argues that there is an extensive body of scientific evidence for adopting new regulations to protect estuarine habitat and the pelagic species dependent on it and that the mechanisms behind the relationships are probably numerous and complex; the other view argues that the biological mechanisms are generally not known.
- ⇨ Ecosystem responses to the location of the low salinity zone in spring and fall are connected, but the connections may be indirect, variable, and dependent upon other factors. Comments also suggest that winter-spring X2 is probably reflective of very different mechanisms than fall X2.
- ⇨ Modeling tools such as CALSIM II can help water resource managers identify strategies for simultaneously meeting Delta salinity targets for resident fishes and upriver temperature targets for migrating chinook salmon, while minimizing impacts on agricultural and urban water supplies.
- ⇨ DRERIP[133] models provide a starting point for predicting how the plant community may change in response to changing salinity regimes.
- ⇨ Some respondents suggest that a causal relationship between the location of the low salinity zone (X2), estuarine habitat quality, and fish abundance would be required, before X2 could be used as a regulatory parameter. Others argue that X2 reflects many processes that affect the aquatic ecosystem and therefore serves as a broad regulatory tool to address ecosystem processes.
- ⇨ Tides and turbidity play a significant role by influencing spawning migrations of delta smelt; however, better information is needed to evaluate these variables as habitat characteristics for various species.
- ⇨ Delta outflows play a key role in supporting concentrations, transport, and duration of exposure effects of contaminants and nutrients in the Delta, but stakeholders are highly divided about what this implies for water quality regulation. Some suggest that EPA should recognize severe modifications to the unimpaired Delta hydrograph as the primary stressor on the Delta ecosystem and that restoration of parts of the hydrograph is an essential element in protecting the aquatic ecosystem. Others have jurisdictional concerns about using the Clean Water Act in regard to flows and that to do so would risk using dilution to solve pollution problems.
- ⇨ Some commenters suggest that performance measures for species population and/or habitat condition would be useful components of integrated assessments of

133 Delta Regional Ecosystem Restoration Implementation Plan

Bay Delta Estuary water quality.

1. **What information is available on the effect of lower salinities in the western Delta on undesirable species such as *Microcystis*, overbite clams, or jellyfish? What, if any, information is available to determine if an increase in low salinity habitat would affect the fate, concentration and distribution of nutrients and toxics that are potentially negatively affecting the estuarine food web?** (3 responses)

Two respondents point to the important role of Delta outflows in supporting dilution processes in the Delta. The representative of a federal resource agency states, "Low salinity habitat is related to Delta outflow, and higher outflows have at least a dilution effect on various pollutants."[134] Two respondents comment on possible regulatory changes for Delta outflows. One respondent suggests that EPA should recognize severe modifications to the unimpaired Delta hydrograph as the primary stressor on the Delta ecosystem:

> The long-term trend of decreased fresh water outflow relative to unimpaired outflow, and recent extremes of this trend, have served to concentrate nutrients and suspected toxins within the low salinity zone of the Delta. For example, Dugdale et al. (2007) indicate that increasing Delta outflow in the spring may alleviate levels of ammonium that potentially impair foodweb productivity.[135]
>
> Recognizing this fact is not at all the same as arguing "dilution as the solution to pollution." Rather, it is to acknowledge that Delta outflows play a critical role in supporting natural dilution and flushing processes in the Delta, and that USEPA can restore this ecosystem process by requiring more natural volumes and temporal patterns of Delta outflow (i.e., a more natural Delta hydrograph).[136]

Water user agencies share scientific and jurisdictional concerns and see no need for EPA action regarding flow. This comment concludes:

> Considering the fact that more favorable flow conditions, which have placed X2[137] in locations considered important for healthy fish populations, have not resulted in increased abundances (Kimmerer et 2009), the predictive ability of X2 is questionable....Use of water rights to modify the location of the LSZ[138] for the purpose of anthropogenic nutrient and toxic discharges would result in an unreasonable use of water in violation of California statutory and constitutional provisions.[139]

2. **Could the frequency, area, and/or duration of low salinity habitat be changed so as to achieve ecosystem benefits for the suite of species that use the low salinity zone? If so, how? Is historical data on inter- or intra- annual frequency of variability the best basis for setting goals or are there other bases that could be used? How might climate change impacts, including sea level rise, affect the size, frequency, and duration of low salinity habitat?** (4 answers)

134 US Fish and Wildlife Service (EPA-R09-OW-2010-0052.1)
135 The Bay Institute (EPA-R09-OW-2010-0040.4)
136 The Bay Institute (EPA-R09-OW-2010-0040.4)
137 X2 = location of the 2 parts per thousand (ppt) salinity gradient; an indicator for the location of the ecologically important low salinity zone.
138 Low salinity zone
139 San Luis Delta & Mendota Water Authority, State Water Contractors (EPA-R09-OW-2010-00 38.1)

There are two distinct views about changing the location of the LSZ to achieve ecosystem benefits.

One respondent cites analyses of the historical relationship between fish abundance, fish population growth, and spatial distribution of several pelagic fish species and winter-spring Delta outflow, as presented in testimony to the State Water Resources Control Board (SWRCB) in 2010:

> In adopting new non-binding flow criteria necessary to protect public trust resources in the Delta, the State Water Resources Control Board (SWRCB 2010) agreed with our findings and translated them into a set of criteria requiring that 75% of unimpaired runoff be dedicated to Delta outflow during the January [-] June period. We concur with the Board's approach as it best simulates the characteristics of a natural hydrograph and provides a clear and simple method for implementing our recommendations.[140]

Other respondents argue that relationships between Delta outflows, the location of the LSZ, and fish populations are not supported by the historical data. "The short answer is that new water quality requirements concerning the low salinity zone would be unlikely to achieve ecosystem benefits because the historical data demonstrates that natural hydrology - and, in particular, trends during wet and dry cycles - are the primary driver of low salinity habitat's characteristics,"[141] states a water user group. And further, "urges USEPA to work with scientists to better evaluate the relationship, if any, between Delta outflow and delta smelt abundance before proposing any fall X2 measure."[142] Generally, respondents agree that a fall X2 standard does not mirror historical hydrological processes, but one respondent considers it a potential tool to protect the threatened Delta smelt:

> Thus, the ecosystem response to fall X2 is different than to spring X2, is of more recent origin, and probably does not reflect processes that operated in the Delta historically…The special nature of the fall X2:abundance relationships notwithstanding, the Delta smelt is in dire jeopardy of extinction and both the Delta smelt and striped bass populations appear to receive substantial protections from supplemental flows in the fall that increase the habitat available during this period (Feyrer et al. 2010). Given this situation, USEPA should develop and promulgate new regulations for fall outflows that will allow Delta fish populations to recover.[143]

A respondent suggests the use of climate change scenarios, developed by the CASCaDE[144] Program (CALFED/USGS funded research), as a basis for predicting possible changes: "Less water and warmer temperatures will probably result in a more lentic[145] Delta ecology rather than one with more water and cooler temperatures which would result in a more lotic[146] Delta ecology."[147]

3. **Are methods available for more systematically addressing ecological or biological connections between springtime X2 and subsequent fall X2 conditions? If so, what are they and what are their strengths and weaknesses?** (3 answers)

One respondent doubts the validity of the question asked, for the lack of scientific evidence that X2

140 The Bay Institute (EPA-R09-OW-2010-0040.4)
141 Northern California Water Association (EPA-R09-OW-2010-0030.1)
142 Northern California Water Association (EPA-R09-OW-2010-0030.1)
143 The Bay Institute (EPA-R09-OW-2010-0040.4)
144 Computational Assessments of Scenarios of Change for the Delta Ecosystem
145 Lentic ("standing") waters; a lake, pond or swamp.
146 Lotic ("flowing") waters; a river, stream, or spring.
147 US Fish and Wildlife Service (EPA-R09-OW-2010-0052.1)

does indeed determine subsequent delta smelt abundance. At the same time, another respondent points to an ongoing study of the question:

> Yes, but the connections don't appear to be direct, may not be constant, and may depend upon other factors. The U.S. Bureau of Reclamation is outlining an Adaptive Management Program to look at this and other mechanisms as required by an RPA[148] (Component #3) contained within the Endangered Species Act consultation on the *Proposed Coordinated Operations of the Central Valley Project (CVP) and State Water Project (SWP)* (USFWS 2008). This program is expected to be initiated in 2011.[149]

As for addressing the most relevant connections, the respondent proposes to examine the relationships between spring X2 conditions and the success of Delta smelt population between the previous fall and the subsequent summer:

> For such an analysis, it will be important to remove the effect of the stock population size on subsequent results (i.e. determine the effect, if any, of outflow conditions on population growth after accounting for abundance of spawners in the previous generation). In addition, USEPA should investigate the effect of winter and spring X2 values on the geographical distribution of Delta smelt spawning (as measured by the spring Kodiak Trawl).[150]

4. **Would changes in system operations to move X2 seaward in the fall adversely affect the reservoir storage needed to conserve salmonid fish spawning and other designated uses in the watershed? Of so, under what conditions?** (3 answers)

A resource management agency and a water user group are concerned that changes in water system operations to move X2 seaward in the fall would come at the cost of other designated uses.

> Yes. Changes in water system operations to move X2 seaward in the fall would adversely affect reservoir storage needed by salmonids in most years. The National Marine Fisheries Service has indicated that there should be a minimum of 2.4 million af[151] of carry-over storage at Shasta Reservoir in order to protect spawning and rearing habitat. ... By contrast, most of the proposals made to the SWRCB would reduce carry-over storage substantially, so that it would only exceed 2.4 million af in approximately 25% of years. [Organization] members presented evidence concerning the very significant impacts that new X2 standards requiring more Delta outflow could have on not only storage levels in Shasta Reservoir on the Sacramento River, but also Folsom Reservoir on the American River and Oroville Reservoir on the Feather River. This evidence demonstrates that such new X2 standards could dramatically reduce reservoir storage levels, which would have the potential to decimate salmonid populations throughout the Sacramento River system. This testimony, as presented by Walter Bourez of MBK Engineers, is available on-line at http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/deltaflow/svwu.shtml, along with all exhibits to that testimony. NCWA strongly

148 "Reasonable and Prudent Alternative" under the Endangered Species Act.
149 US Fish and Wildlife Service (EPA-R09-OW-2010-0052.1)
150 US Fish and Wildlife Service (EPA-R09-OW-2010-0052.1)
151 Acre-feet

> urges USEPA to reject any proposed changes in water system operations that would have such an adverse effect on the many species that are listed as either threatened or endangered under the federal Endangered Species Act.[152]
>
> There is a likely cost when stored water reserves are used elsewhere in the system. The Department of Water Resources (DWR), and USBR have the required modeling tools to answer this question fairly accurately. A range of water year types can be examined using CALSIM II, and several available water temperature models can evaluate potential temperature effects to the Sacramento River.[153]

Another respondent suggests moving X2 westward only following wet and above normal years. Rather than impacting reservoir storage in the subsequent year, water releases in fall seasons following wet and above normal years would benefit Chinook salmon, by compensating for typically low fall releases owed to the lack of demand from water users in such years. As the respondent concludes:

> We believe that if these fall X2 requirements are implemented along with the NMFS Biological Opinion RPA (NMFS 2009; RPA Actions I.2.1 to I.2.4), then any impacts to carryover storage and coldwater pool will be minimal.[154]

The ultimate goal, as all three answers suggest, would be to achieve consistency between ecosystem benefits for the Delta species using the LSZ and implementing the NMFS Biological Opinion on the Central Valley Project focused on salmonids, while minimizing impacts on agricultural and urban water supplies.

5. **What information is available on the effects of salinity management on terrestrial plant communities and/or tidal marsh endemic species? What indirect effects does this have on the aquatic communities?** (2 answers)

One respondent refers to the wealth of literature on the subject of plant species distribution versus salinity in the soil and surface water. The respondent cites a study of the role of sedimentation in marsh development in the estuary (Culberson et el 2004), to support that plant community movement and plant performance over time, while not definitive, can be reasonably predicted. The respondent notes further that effects of salinity management on aquatic communities are difficult to measure. Therefore, conceptual models such as the DRERIP models should be used and CALFED ERP documents may provide a useful source of information. The second respondent proposes that the desired natural communities depend on natural variability in salinity and that X2 should be managed accordingly.

6. **Does the geographic location of low-salinity habitat have an effect on the quality of the habitat or its availability to species of concern? If so, what is the nature and extent of such effect? Is the distribution pattern of low salinity habitat important in determining its quality?** (3 answers)

Respondents suggest that any proposed relationship between the location of the low salinity zone (X2), estuarine habitat quality, and fish abundance requires scientific validation. Disagreement

152 Northern California Water Association (EPA-R09-OW-2010-0030.1)
153 US Fish and Wildlife Service (EPA-R09-OW-2010-0052.1)
154 The Bay Institute (EPA-R09-OW-2010-0040.4)

centers on the requirement for causal relationships to be the basis of protective actions. One respondent puts it this way:

> It is often assumed that the position of the low salinity zone, with respect to shallow shoals or tidal wetlands, is responsible for the winter-spring X2:abundance relationships that are so well- documented in the literature. In fact, this is only one of several potential explanations for the winter-spring X2(outflow):abundance relationships (Kimmerer 2002b). …If the position of the 2ppt isohaline[155] relative to other habitat features was responsible for the improved performance of pelagic species when winter-spring X2 moves west, then one would expect to detect a threshold value for X2 that was consistent across species. No such threshold X2 value has been detected for any population studied in the Bay-Delta.[156]

A spokesperson for water agencies states that it is problematic to assume that the X2 location is a reliable habitat indicator for Delta smelt and other species:

> First, it does not account for the fact that each species that resides in the Bay-Delta has its own unique habitat, which is defined as the geographic area that supports a suite of physical and biotic resources upon which the species depends for its survival and reproduction…. Second, the use of X2 in resource management planning as a surrogate habitat parameter is scientifically problematic, unless it has been validated that X2 correlates well in its spatially and temporal distribution with the suite of physical and biological resources required by the targeted species.[157]

A resource agency representative answers that research is currently being conducted to address the question and referred to the *Interagency Ecological Program (IEP) 2011 Work Plan.*

7. Are spring/neap differences in tidal water quality important for aquatic species? If so, how should these habitat characteristics be evaluated? (2 answers)

One respondent suggests that tides and turbidity play a significant role by influencing spawning migrations of delta smelt, and that better information is needed to evaluate these variables as habitat characteristics for various species. "Additional study is needed to determine the historical and current primary causes of turbidity in the various sub-regions of the Bay-Delta. Without an understanding of the causes of turbidity on a sub-regional basis, it will be difficult to assess on a species-by-species basis, the importance of tidal water quality as measured by turbidity."[158] Another respondent suggests that, based on recent findings (Enright et al. (in preparation), spring/neap differences in tidal water quality may be discernable at the landscape level but that showing what the links are to aquatic species performance will be unlikely for some time.

8. How can performance measures for species population and/or habitat condition be used to evaluate restoration of Bay Delta Estuary water quality? (3 answers)

One respondent notes that such performance measures require an appropriate context to be

155 Of equal or constant salinity. A line on a chart connecting all points of equal salinity
156 The Bay Institute (EPA-R09-OW-2010-0040.4)
157 San Luis Delta & Mendota Water Authority, State Water Contractors (EPA-R09-OW-2010-00 38.1)
158 San Luis Delta & Mendota Water Authority, State Water Contractors (EPA-R09-OW-2010-00 38.1)

properly evaluated, since there are many additional environmental and anthropogenic factors determining water quality. Another respondent recommends developing specific performance targets as a basis for regulatory standards. And another, "In developing and promulgating new water quality regulations, USEPA should articulate specific goals and quantifiable objectives for desired conditions in the Bay-Delta (i.e. what does a functioning," healthy" ecosystem look like, as defined using attributes of population viability and ecosystem health) and then identify which of these goals will be served by specific improvements in water quality and to what extent."[159]

FISH MIGRATION CORRIDORS

Seven respondents answered questions on migratory corridors, including resource management agencies (3), water agencies (2), an environmental organization (1), and a regulated discharger (1).

Key Points

- ⇨ Some respondents express concerns over disrupted physical-chemical gradients as a barrier to salmon migration in the San Joaquin River system, whereas others suggest that the available data are insufficient to demonstrate that such gradients affect the migratory corridor for salmon.
- ⇨ Respondents identify physical and chemical as well as biological measures for protecting fish migration designated uses.
- ⇨ Respondents confirm that temporal characteristics of a migration corridor should be considered in relation to the survival of salmon.
- ⇨ Respondents suggest that concerns over the restoration success of migratory corridors might be addressed or alleviated by ensuring adequate flows in the Lower San Joaquin River.
- ⇨ Proposed options for improving dissolved oxygen regimes in the Delta include the full implementation of an existing TMDL for the San Joaquin River Deep Water Ship Channel, using EPA's existing Clean Water Act authorities to more stringently enforce the Act, and new regulations for San Joaquin River inflows.
- ⇨ Additional barriers to fish migration in the Bay Delta Estuary that are not covered by the ANPR are the Yolo Bypass and Suisun Marsh.

1. **What role, if any, do gradients in physical and chemical constituents of water play in the suitability of the Bay Delta Estuary and San Joaquin River Basin migratory corridor for adult salmon?** (5 responses)

Several respondents share concerns over disrupted physical-chemical gradients as a barrier to salmon migration in the San Joaquin River system. One commenter notes that it is uncertain whether the needed migratory corridor between the San Joaquin River and Pacific Ocean can be maintained by permitting exports from the south Delta that exceed San Joaquin inflows by a 3:1 ratio. Other respondents suggest that the available data are insufficient to demonstrate that

159 The Bay Institute (EPA-R09-OW-2010-0040.4)

gradients in the physical and chemical constituents of water in the Bay-Delta and San Joaquin River system affect the migratory corridor for salmon.

2. **What are the best measures of success for restoration of a migratory corridor? Could these measures be incorporated into new or revised biological criteria protecting the fish migration designated use?** (4 responses)

Respondents identify physical and chemical as well as biological measures for protecting fish migration designated uses: “Rather than defining water quality and flow criteria only, biological criteria that more directly measure fish migration and spawning success could be developed and used.”[160]

One federal resource management agency suggests specific measures of success that could be used as a basis for biological criteria:

> Metrics for determining the success of restoration efforts to improve migratory corridors could include: increased downstream juvenile salmonid survival, increased access to and acreage of floodplain rearing habitat, improved habitat complexity, reductions in bottlenecks and predatory hotspots, reductions in water temperatures, improvements in dissolved oxygen and other water quality parameters, and increased flow/reductions in travel time for juvenile salmonids to overcome tidal barriers. Such information could be used in developing criteria to meet fish migration objectives in the Water Quality Control Plan.[161]

Other respondents -- including another federal resource management agency, an environmental organization, and a regulated discharger-- recommend additional metrics for measuring success, such as direct counting of adult salmonids passing specified locations in the river system, the fraction of the migration season that the corridor remains open, and the frequency (in terms of years) that the migration corridor is open for the full migration season.

3. **Should temporal characteristics be included in the definition of the physical and/or chemical properties of a migration corridor based on a reference condition? If so, how? What frequency and duration of such a corridor is required for salmonids? How might these characteristics change with the impacts of climate change?** (4 responses)

Respondents confirm that the timing of a migration corridor should be considered in relation to the survival of salmon and raised several points: “Parameters for protecting migrating fishes and maintaining migration corridors should provide a seasonal component that considers the most sensitive species that are likely to be migrating seasonally”, states on respondent.[162]

Another respondent makes a related point: “The baseline for determining the migration period for different fishes in the Delta must be based on our knowledge of seasonality and variability in the life cycle of the species of interest.”[163] Referring to conceptual models developed as part of the CALFED Ecosystem Restoration Program’s DRERIP process (e.g. Rosenfield 2010), this respondent proposes to base timing, initiation, and duration of protections for migration corridors in relation to the expected range of timing for each species’ various life history stages portrayed in the DRERIP models. “Because the life histories of native fishes are very often cued to flow patterns in

160 Sacramento Regional County Sanitation District (EPA-R09-OW-2010-0022.1)
161 National Oceanic and Atmospheric Administration (EPA-R09-OW-2010-0050.1)
162 Sacramento Regional County Sanitation District (EPA-R09-OW-2010-0022.1)
163 The Bay Institute (EPA-R09-OW-2010-0040.4)

the Delta and these life histories probably evolved to capitalize on these flow patterns, the knowledge assembled in the DRERIP (or other) conceptual models must be combined with estimates of unimpaired flow patterns to form a baseline for a USEPA water quality performance metric."[164]

4. **Would establishing a migratory corridor for upmigrating adult Chinook salmon succeed in improving adult migration success if temperatures in the river channels upstream of Vernalis are unchanged? If so, how? How might actions to establish a migratory corridor in the south Delta also moderate temperature and/or dissolved oxygen problems in the San Joaquin River?** (2 answers)

Both respondents raise various issues that would need to be considered for a salmon migratory corridor to succeed. Both suggest that adequate flows in the Lower San Joaquin River might address or alleviate these issues.

For example:

> Any change in system hydrology could affect the physical, chemical, and biotic processes, and thus can affect related temperature and DO[165] conditions in the San Joaquin River.... Based on the identified need for additional studies to resolve the *existing* DWSC[166] DO impairment, it is apparent that it is unlikely that there is sufficient data or analytical techniques or modeling available at this time to predict how improving migratory conditions in the South Delta might change the lower San Joaquin River-South Delta temperature and DO conditions. That said, moving greater volumes of water through the system has the potential to improve both temperature and DO conditions in this portion of the system where flows have been low, and thus, water exchange rates have also been low.[167]

5. **What additional efforts to improve dissolved oxygen regimes in the Delta are necessary to provide an adequate migratory corridor for San Joaquin salmonids?** (3 responses)

The respondents express concerns about efforts beyond the Central Valley Regional Water Board's Dissolved Oxygen TMDL for the Lower San Joaquin River Deep Water Ship Channel. "[Our organization] does not support development of additional solutions for DO impairments in the DWSC until the current studies are completed and a determination of long-term solutions can be made," says one respondent who feels that supporting the implementation of studies and actions required by the Dissolved Oxygen TMDL for the DWSC was the best approach.[168] Or another, "EPA should use its Clean Water Act authorities to enforce the Act and ensure the TMDL is being achieved."[169] The head of an environmental organization disagrees with these positions:

> Additional efforts to eliminate dissolved oxygen impairment on the lower San Joaquin River are essential to restoring salmonids and other migratory fish (anadromous and pelagic) to the San Joaquin watershed. ...USEPA should develop and promulgate new regulations for San Joaquin inflows throughout the year in order to protect

164 The Bay Institute (EPA-R09-OW-2010-0040.4)
165 Dissolved oxygen
166 Deep Water Ship Channel
167 Sacramento Regional County Sanitation District (EPA-R09-OW-2010-0022.1)
168 Sacramento Regional County Sanitation District (EPA-R09-OW-2010-0022.1)
169 Westlands Water District (EPA-R09-OW-2010-0037.1)

spatial distribution (e.g. spawning in the San Joaquin River and its tributaries) of public trust resources that use the Delta as a migratory corridor.[170]

6. **What other information is available on the barriers to salmon migration on the San Joaquin River system?** (2 responses)

Fremont Weir in the Yolo Bypass and the operation of salinity control gates in Suisun Marsh are mentioned as additional barriers to migration in the Bay Delta Estuary that are not covered in the ANPR. Studies published and compiled by the San Joaquin River Restoration Program and studies done in the Central Valley by biologists from various resource agencies (National Marine Fisheries Service, California Department of Fish and Game, DWR) are suggested as additional information sources on the issue.

WETLANDS

Five respondents answered questions on wetlands, including resource management agencies (2), an environmental organization (1), a private individual (1), and a regulated discharger (1).

Key Points

- ⇨ Respondents propose to consider ecological functions when permitting wetland activities, and develop ecosystem viability criteria for use in the permitting process.
- ⇨ Areas with concentrations of wetlands within the estuary (Suisun Marsh, for example) have consistently shown to have relatively higher populations of native fishes associated with them.
- ⇨ Protecting the integrity of hydro-geomorphic and ecological processes, along with the protection of upland buffer areas, are critical to the continuing evolution and existence of tidal marshes within the Estuary.

1. **What different approaches under the Clean Water Act Section 404 program should EPA consider, in consultation with the U.S. Army Corps of Engineers, to improve the protection of aquatic resource functions in the Bay Delta Estuary?** (5 responses)

Not all answers directly address the question, but those that do comment on the need to more fully consider ecological functions. One respondent proposes to explicitly consider the landscape level values of wetlands when permitting wetland activities, and develop ecosystem viability criteria for use in the permitting process.

2. **What information exists that describes the relationship between the quantity and quality of wetlands and Bay Delta Estuary water quality and fish populations?** (3 responses)

Not surprisingly, all respondents point to the scarcity of existing information on these relationships and, consequently, suggest further research in this area or making inferences from whatever information is available for the Bay-Delta and elsewhere. "Various monitoring efforts, such as those

170 The Bay Institute (EPA-R09-OW-2010-0040.4)

performed in Suisun Marsh and Yolo Bypass, can provide inferences about the relationship between the quantity and quality of wetland habitat and fish abundance/health, "[171]states one respondent, and another:

> Very little information is available on the relation between these variables. It is known from other estuaries and in concept. There is information that suggests that the floodplain function of the Yolo Bypass is beneficial to out-migrating salmonid growth (DWR/IEP and other references). Areas with concentrations of wetlands within the Estuary (Suisun Marsh, for example) have consistently shown to have relatively higher populations of native fishes associated with them (University of California-Davis reports, Schroeter and Moyle 2002, Matern et al 2002).[172]

3. **In light of projected impacts of climate change (including sea level rise and its effects on levee stability), what specific activities can EPA undertake to improve long-term protection of existing and future wetlands, especially those resources on subsided islands?** (3 comments)

One answer specifically addresses the question asked, i.e. what specific activities EPA can undertake to improve long-term protection of existing and future wetlands. The respondent, representing a federal resource agency, suggests:

> Tidal wetlands with good internal integrity and adjacent upland areas should allow wetland adaptation and movement with sea level change. Protecting hydrobiogeomorphic integrity and processes are critical to the continuing evolution and existence of tidal marshes within the Estuary. Subsided lands will need restoration efforts to accumulate sediments or organic matter prior to fully return to tidal influence before they can provide tidal marsh functions.[173]

The respondent also points out that, "Protection of buffer lands is critical to the future of tidal marsh habitat."[174] One other respondent affirms the importance for EPA to take actions, whereas another suggests that, "Better information on how much sea level is anticipated to rise is needed for [farmers] to develop a plan on how to adapt their operations to prepare for the changes."[175]

CONCLUSION

There is a great deal of concern over future policy decisions affecting the Delta's resources, and this appears to have motivated many of the responses to the ANPR. At the core of these concerns are the values the Delta provides as a natural resource: "The California Delta is one of the greatest national assets we have", states a local resident.[176] Others provide related comments:

171 National Oceanic and Atmospheric Administration (EPA-R09-OW-2010-0050.1)
172 US Fish and Wildlife Service (EPA-R09-OW-2010-0052.1)
173 US Fish and Wildlife Service (EPA-R09-OW-2010-0052.1)
174 US Fish and Wildlife Service (EPA-R09-OW-2010-0052.1)
175 County of Sacramento (EPA-R09-OW-2010-0020.1)
176 Jamie Carey (EPA-R09-OW-2010-008)

> The Delta supports a statewide agricultural industry that generates more than $30 billion in revenue annually and provides drinking water for tens of millions of California residents. Similarly, the state's salmon fishing industries — and the thousands of jobs they sustain — depend on the health of the Delta estuary....The San Joaquin Delta is far more, however, than a simple water resource for the state. The Delta is a unique place with a distinct economic and cultural heritage.[177]

> The residents of [our jurisdiction] rely on the Delta for their municipal and industrial water supply, for fishing and other forms of recreation, for work and as a place to live. The County has a strong interest in protecting Delta water quality, restoring the Delta sustainable ecosystem, and preserving the values of the Delta place to live, work and enjoy. The County looks to EPA as a leader by taking an independent look at the panoply of issues impacting the Bay-Delta today and providing its scientific expertise as necessary components of a comprehensive solution to these problems.[178]

Due to the Delta's significance and the complexity of issues, respondents appreciate the opportunity to provide input in EPA's strategic planning process. A representative of a large statewide discharger association puts it this way:

> We commend U.S. EPA Region 9 for soliciting broad-based input to assist it with developing a strategy to collaborate with the state of California on protecting the Delta, which is a vital national resource. We understand that U.S. EPA seeks input on all types of possible actions to protect Delta water quality, including but not limited to actions that would require rulemaking.[179]

The representative of a regulatory agency makes the same point: " Staff also appreciates the chance for regulators and other stakeholders to be part of that evaluation through the ANPR."[180] A public representative summarizes the widely shared expectation to be heard, here on behalf of his constituency:

> Thank you for soliciting public input on actions the Environmental Protection Agency (EPA) could potentially take to address water quality challenges in the Sacramento-San Joaquin Delta. As EPA considers future policy decisions, I insist that you closely consider the public comments you receive from residents of the San Joaquin Delta region.[181]

The intent of the ANPR was not always clearly understood by respondents. Most respondents appeared to understand that the ANPR was designed as an information gathering process for evaluating water quality challenges affecting fish and other estuarine resources in the Bay Delta Estuary. Seeking public comment through the ANPR was the first step in evaluating whether the EPA should be taking new or different actions under its programs to more effectively address water quality problems in the Bay Delta Estuary. However, several respondents seemed to think EPA issued the ANPR as a first step in asserting expanded regulatory and enforcement authority in the region. The following comments are representative of this confusion:

---

177 Jerry McNerney, Congress of the United States, House of Representatives (EPA-R09-OW-2010-061.1)
178 Contra Costa County Department of Conservation and Development (EPA-R09-OW-2010-0049)
179 California Stormwater Quality Association (EPA-R09-OW-2010-0045.1)
180 Central Valley Regional Water Quality Control Board (EPA-R09-OW-2010-00 21.1)
181 Jerry McNerney, Congress of the United States, House of Representatives (EPA-R09-OW-2010-061.1)

> The EPA seems to be treating this ANPR as the first step in EPA's assertion of enforcement jurisdiction over violations of California's NPDES permitting program.[182]
>
> As noted earlier in this letter, [we] are concerned that the Bay-Delta ANPR, after it discusses the too-long ignored key water quality issues that need priority attention, strays into flow related, state water rights issues that are outside federal jurisdiction.[183]
>
> We provide this information in hopes that the EPA can update and amend its scientific information, and with the caution that any rulemaking or regulatory action based on the current information… would not be defensible.[184]

More commonly, though, commenters welcome EPA's renewed commitment to addressing the Delta's serious water quality issues. And by the same token, commenters express support for the ANPR as an appropriate step in the right direction. One respondent, for example, states: "The [respondent] is pleased that EPA has begun to engage in a more comprehensive strategic planning process than in the past, recognizes the complexity of the environmental issues in the Delta, and has identified many of the diverse stressors that are acting on the Delta ecosystem."[185]

Repeatedly, respondents welcome the initiative as an opportunity for addressing the Delta's issues through improved coordination. One respondent states, "Given these challenging tasks, we are encouraged by EPA's efforts to address water quality conditions affecting aquatic resources in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. To help coordinate our efforts with those of EPA, we offer the following comments on [the ANPR]. The [organization] is concerned with Delta water quality and any potential adverse impacts it may have on human health, the ecosystem and water supply. ….In 2010, the State Water Resources Control Board (Water Board) indicated that some of the most serious water quality problems in the Delta watershed and all of California are related to nonpoint source. The Water Board has programs to address these sources, but there remains a strong need to address the management of pollutants that are discharged from both and nonpoint sources into the Delta…. although significant efforts to address water quality problems in the Delta have already been implemented or are in development, we believe that this action by EPA is timely. State and federal agency assessments of Delta water quality continue to identify impairment of beneficial uses. Should EPA choose to take action to address Delta water quality problems, the following would be most helpful."[186]

In large and general, respondents view the ANPR as an opportunity to improve the effectiveness of regulations and the investment of public funding. As one respondent states:

> I am encouraged by EPA's investigations into new approaches to address water quality in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary.[187]

182 San Joaquin River Exchange Contractors Water Authority (EPA-R09-OW-2010-031.1)
183 San Luis Delta & Mendota Water Authority, State Water Contractors (EPA-R09-OW-2010-00 38.1)
184 San Joaquin River Group Authority (EPA-R09-OW-2010-00 29.1)
185 Coalition for a Sustainable Delta (EPA-R09-OW-2010-0043.1)
186 Delta Stewardship Council (EPA-R09-OW-2010-0057.1)
187 Environmental Incentives, LLC (EPA-R09-OW-2010-0046)

Appendices

Appendix A: Tables

Table 1: Response, by submission type

	Number	Percent each submission type	Percent total
All responses			
Federal Rulemaking Portal	40	100	73
Email[1]	11	100	20
Hardcopy[2]	4	100	7
TOTAL	**55**		**100**
Prepared Letters			
Federal Rulemaking Portal	30	75	55
Email[1]	3	27	6
Hardcopy[2]	4	100	7
Total	**37**		**67**
Additional Information			
Federal Rulemaking Portal	16	40	29
Email[1]	4	36	7
Hardcopy[2]	1	25	2
Total	**21**		**38**

1. Responses submitted only by email, excluding responses that were simultaneously submitted to the Federal Rulemaking Portal.
2. Responses submitted only by hardcopy, excluding responses that were simultaneously submitted to the Federal Rulemaking Portal or by email.

Table 2: Response, by affiliation

	Number	Percent
Response		
Affiliated[1]	32	58
Not affiliated[2]	23	42
TOTAL	**55**	100

1. Responses submitted on behalf of an organization.
2. Responses submitted by private individuals or small business owners.

Table 3: Response, by sector

	Number	Percent
Sector		
Academia	1	2
Government	15	27
Join powers authorities	1	2
Membership associations	8	15
Non-governmental organizations	6	11
Private business	6	11
Private individuals	16	29
Special status public agencies	2	4
TOTAL	**55**	**100**

Table 4: Response, by government agency type

	Number	Percent
Agency type		
Federal	4	27
Local	3	20
Regional	4	27
State	4	27
TOTAL	**15**	**100**

Table 5: Response, by perspective

	Number total	Percent total
Perspective		
Commodity group	1	2
Consultant	2	4
Environmental advocacy	6	11
Private individual/business	21	38
Regulated discharger	6	11
Regulatory authority	3	6
Research	1	2
Resource policy, planning, and management	9	16
Water agency	4	7
Water user	2	4
TOTAL	**55**	**100**

Table 6: Response to each topic, by perspective[1]

	Number	Percent each perspective	Percent total	Percent, excluding generic responses[2]
Contaminants				
Perspective				
Commodity group	0	0		0
Consultant	0	0		n/a
Environmental advocacy	2	33		40
Private individual/business	1	5		25
Regulated discharger	3	50		50
Regulatory authority	0	0		0
Research	0	0		n/a
Resource policy, planning, & mgmt	2	22		33
Water agency	0	0		0
Water user	0	0		0
Total response	**8**		**15**	**27**
Ammonia: Toxic and Nutrient Effects				
Perspective				
Commodity group	0	0		0
Consultant	0	0		n/a
Environmental advocacy	1	17		20
Private individual/business	0	0		0
Regulated discharger	3	50		50
Regulatory authority	0	0		0
Research	0	0		n/a
Resource policy, planning, & mgmt	2	22		33
Water agency	2	50		50
Water user	0	0		0
Total response	**8**		**15**	**27**
Selenium				
Perspective				
Commodity group	0	0		0
Consultant	0	0		n/a
Environmental advocacy	4	67		80
Private individual/business	1	5		25
Regulated discharger	2	33		33
Regulatory authority	1	33		50
Research	0	0		n/a
Resource policy, planning, & mgmt	2	22		33

Water agency	2	50		50
Water user	0	0		0
Total response	**12**		**22**	**40**

Table 6 (continued): Response to each topic, by perspective[1]

	Number	Percent each perspective	Percent total	Percent, excluding generic responses[2]
Pesticides				
Perspective				
Commodity group	1	100		100
Consultant	0	0		n/a
Environmental advocacy	2	33		40
Private individual/business	0	0		0
Regulated discharger	5	83		50
Regulatory authority	2	67		100
Research	0	0		n/a
Resource policy, planning, & mgmt	5	56		83
Water agency	2	50		50
Water user	1	50		50
Total response	**18**		**33**	**60**
Contaminants of Emerging Concern				
Perspective				
Commodity group	0	0		0
Consultant	0	0		n/a
Environmental advocacy	1	17		20
Private individual/business	1	5		25
Regulated discharger	3	50		50
Regulatory authority	0	0		0
Research	0	0		n/a
Resource policy, planning, & mgmt	1	11		17
Water agency	1	25		25
Water user	0	0		0
Total response	**7**		**13**	**23**
Estuarine Habitat				
Perspective				
Commodity group	0	0		0
Consultant	0	0		n/a
Environmental advocacy	2	33		40
Private individual/business	0	0		0
Regulated discharger	0	0		0
Regulatory authority	0	0		0
Research	0	0		n/a
Resource policy, planning, & mgmt	1	11		17
Water agency	1	25		25

Water user	1	50		50
Total response	**5**		**9**	**17**

Table 6 (continued): Response to each topic, by perspective[1]

	Number	Percent each perspective	Percent total	Percent, excluding generic responses[2]
Fish Migration Corridors				
Perspective				
Commodity group	0	0		0
Consultant	0	0		n/a
Environmental advocacy	1	17		20
Private individual/business	0	0		0
Regulated discharger	1	17		17
Regulatory authority	0	0		0
Research	0	0		n/a
Resource policy, planning, & mgmt	3	33		50
Water agency	2	50		50
Water user	0	50		50
Total response	**7**		**13**	**23**
Wetlands				
Perspective				
Commodity group	0	0		0
Consultant	0	0		n/a
Environmental advocacy	1	17		20
Private individual/business	1	5		25
Regulated discharger	1	17		50
Regulatory authority	0	0		0
Research	0	0		n/a
Resource policy, planning, & mgmt	2	22		33
Water agency	0	0		25
Water user	0	0		0
Total response	**5**		**9**	**17**
Additional Comments[3]				
Perspective				
Commodity group	1	100		
Consultant	2	100		
Environmental advocacy	5	83		
Private individual/business	18	86		
Regulated discharger	3	67		
Regulatory authority	2	100		
Research	1	100		

Resource policy, planning, & mgmt	9	100	
Water agency	4	100	
Water user	1	50	
Total response	**46**		**84**

1. Responses addressing one, several, or all questions to a topic.
2. Excluding responses not addressing any of the specific questions.
3. General comments not addressing any specific question.

Table 7: Response, by interest

	Number total	**Percent total**
Interest		
Agriculture	2	4
Boating	1	2
Environmental protection	5	9
Land use	1	2
Natural resources management	7	13
Public involvement	25	46
Renewable energy	1	2
Science	1	2
Stormwater	2	4
Wastewater	3	6
Water supply	7	13
TOTAL	**55**	**100**

Table 8: Response, by involvement

	Number total	**Percent total**
Involvement		
Business/industry	11	20
Environmental group	6	11
Federal agency/national authority	4	8
Local agency/authority	5	9
Personal	12	22
Recreational group	1	2
Regional agency/authority	9	16
State agency/authority	5	9
TOTAL	**55**	**100**

Table 9: Response to each topic, by interest in the Delta[1]

	Number	Percent each group	Percent total	Percent, excluding generic responses[2]
Contaminants				
Interest				
Agriculture	0	0		0
Boating	0	0		n/a
Environmental protection	0	0		0
Land use	0	0		n/a
Natural resources management	2	29		33
Public involvement	3	12		33
Renewable energy	0	0		n/a
Science	0	0		n/a
Stormwater	1	50		50
Wastewater	2	67		67
Water supply	0	0		0
Total response	**8**		**15**	**27**
Ammonia: Toxic and Nutrient Effects				
Interest				
Agriculture	0	0		0
Boating	0	0		n/a
Environmental protection	0	0		0
Land use	0	0		n/a
Natural resources management	2	29		33
Public involvement	1	4		11
Renewable energy	0	0		n/a
Science	0	0		n/a
Stormwater	1	50		50
Wastewater	2	67		67
Water supply	2	29		33
Total response	**8**		**15**	**27**

•

Table 9 (continued): Response to each topic, by interest in the Delta[1]

	Number	Percent each group	Percent total	Percent, excluding generic responses[2]
Selenium				
Interest				
Agriculture	0	0		0
Boating	0	0		n/a
Environmental protection	1	20		50
Land use	0	0		n/a
Natural resources management	2	29		33
Public involvement	5	20		56
Renewable energy	0	0		n/a
Science	0	0		n/a
Stormwater	0	0		0
Wastewater	2	67		67
Water supply	2	29		33
Total response	**12**		**22**	**40**
Pesticides				
Interest				
Agriculture	2	100		100
Boating	0	0		n/a
Environmental protection	2	40		100
Land use	0	0		n/a
Natural resources management	5	71		83
Public involvement	2	8		22
Renewable energy	0	0		n/a
Science	0	0		n/a
Stormwater	2	100		100
Wastewater	2	67		67
Water supply	3	43		50
Total response	**18**		**33**	**60**

Table 9: Response (continued): Response to each topic, by interest in the Delta[1]

	Number	Percent each group	Percent total	Percent, excluding generic responses[2]
Contaminant of Emerging Concern				
Interest				
Agriculture	0	0		0
Boating	0	0		n/a
Environmental protection	0	0		0
Land use	0	0		n/a
Natural resources management	1	14		17
Public involvement	2	8		22
Renewable energy	0	0		n/a
Science	0	0		n/a
Stormwater	1	50		50
Wastewater	2	67		67
Water supply	1	14		17
Total response	**7**		**13**	**23**
Estuarine Habitat				
Interest				
Agriculture	0	0		0
Boating	0	0		n/a
Environmental protection	0	0		0
Land use	0	0		n/a
Natural resources management	1	14		17
Public involvement	2	8		22
Renewable energy	0	0		n/a
Science	0	0		n/a
Stormwater	0	0		0
Wastewater	0	0		0
Water supply	2	29		33
Total response	**5**		**9**	**17**

Table 9: Response (continued): Response to each topic, by interest in the Delta[1]

	Number	Percent each group	Percent total	Percent, excluding generic responses[2]
Fish Migration Corridors				
Interest				
Agriculture	0	0		0
Boating	0	0		n/a
Environmental protection	0	0		0
Land use	0	0		n/a
Natural resources management	3	43		50
Public involvement	1	4		11
Renewable energy	0	0		n/a
Science	0	0		n/a
Stormwater	0	0		0
Wastewater	1	33		33
Water supply	2	29		33
Total response	**7**		**13**	**23**
Wetlands				
Interest				
Agriculture	0	0		0
Boating	0	0		n/a
Environmental protection	0	0		0
Land use	0	0		n/a
Natural resources management	2	29		33
Public involvement	2	8		22
Renewable energy	0	0		n/a
Science	0	0		n/a
Stormwater	1	50		50
Wastewater	0	0		0
Water supply	0	0		0
Total response	**5**		**9**	**17**

Table 9: Response (continued): Response to each topic, by interest in the Delta[1]

	Number	Percent each group	Percent total
Additional Comments[3]			
Interest			
Agriculture	1	50	
Boating	1	100	
Environmental protection	4	80	
Land use	1	100	
Natural resources management	7	100	
Public involvement	21	84	
Renewable energy	1	100	
Science	1	100	
Stormwater	1	50	
Wastewater	2	67	
Water supply	6	86	
Total response	**46**		**84**

1. Responses addressing one, several, or all questions to a topic.
2. Excluding responses not addressing any of the specific questions.
3. General comments not addressing any specific question.

Table 10: Response to each topic, by involvement in the Delta[1]

	Number	Percent each type of involvement	Percent total	Percent, excluding generic responses[2]
Contaminants				
Involvement				
Business/industry	1	9		17
Educational	0	0		n/a
Environmental group	2	33		40
Federal agency/national authority	1	25		33
Local agency/authority	0	0		0
Personal	0	0		0
Recreational group	0	0		n/a
Regional agency/authority	3	33		38
State agency/authority	1	20		25
Total response	**8**		**15**	**27**
Ammonia: Toxic and Nutrient Effects				
Involvement				
Business/industry	0	0		0
Educational	0	0		n/a
Environmental group	1	17		20
Federal agency/national authority	2	50		67
Local agency/authority	1	20		50
Personal	0	0		0
Recreational group	0	0		0
Regional agency/authority	4	44		50
State agency/authority	0	0		0
Total response	**8**		**15**	**27**
Selenium				
Involvement				
Business/industry	2	18		33
Educational	0	0		n/a
Environmental group	4	67		80
Federal agency/national authority	1	25		33
Local agency/authority	1	20		50
Personal	1	8		50
Recreational group	0	0		n/a
Regional agency/authority	2	22		25
State agency/authority	1	20		25

Total response	**12**	**22**	**40**

Table 10 (continued): Response to each topic, by involvement in the Delta[1]

	Number	Percent each type of involvement	Percent total	Percent, excluding generic responses[2]
Pesticides				
Involvement				
Business/industry	2	18		33
Educational	0	0		n/a
Environmental group	2	33		40
Federal agency/national authority	2	50		67
Local agency/authority	1	20		50
Personal	0	0		0
Recreational group	0	0		n/a
Regional agency/authority	7	78		88
State agency/authority	4	80		100
Total response	**18**		**33**	**60**
Contaminants of Emerging Concern				
Involvement				
Business/industry	0	0		0
Educational	0	0		n/a
Environmental group	1	17		20
Federal agency/national authority	1	25		33
Local agency/authority	1	20		50
Personal	1	20		50
Recreational group	0	0		n/a
Regional agency/authority	3	33		38
State agency/authority	0	0		0
Total response	**7**		**13**	**23**
Estuarine Habitat				
Involvement				
Business/industry	1			
Educational	0			
Environmental group	2			
Federal agency/national authority	1			
Local agency/authority	1			
Personal	0			
Recreational group	0			
Regional agency/authority	0			
State agency/authority	0			
Total response	**5**		**9**	**17**

Table 10 (continued): Response to each topic, by involvement in the Delta[1]

	Number	Percent each perspective	Percent total	Percent, excluding generic responses[2]
Fish Migration Corridors				
Involvement				
Business/industry	0	0		0
Educational	0	0		n/a
Environmental group	1	17		20
Federal agency/national authority	3	75		100
Local agency/authority	1	20		50
Personal	0	0		0
Recreational group	0	0		n/a
Regional agency/authority	2	22		25
State agency/authority	0	0		0
Total response	**7**		**13**	**23**
Wetlands				
Involvement				
Business/industry	0	0		0
Educational	0	0		n/a
Environmental group	1	17		20
Federal agency/national authority	3	75		100
Local agency/authority	0	0		0
Personal	0	0		0
Recreational group	0	0		n/a
Regional agency/authority	1	11		13
State agency/authority	0	0		0
Total response	**5**		**9**	**17**

Table 10 (continued): Response to each topic, by involvement in the Delta[1]

Total response	**5**	**9**	**17**
Additional Comments[3]			
Involvement			
Business/industry	7	64	
Educational	1	100	
Environmental group	5	83	
Federal agency/national authority	4	100	
Local agency/authority	5	100	
Personal	10	83	
Recreational group	1	100	
Regional agency/authority	9	100	
State agency/authority	4	80	
Total response	**46**	**84**	

1. Responses addressing one, several, or all questions to a topic.
2. Excluding responses not addressing any of the specific questions.
3. General comments not addressing any specific question.

Appendix B: List of Respondents

AquAlliance, Chico, CA
Marcus Balanky
Bay Area Clean Water Agencies
Gene Beley, Stockton, CA
Jim Bell
Pat Borison
David Brown, Elk Grove, CA
California Coastkeeper Alliance, Fremont, CA
California Department of Pesticide Regulation
California Natural Resources Agency, Sacramento, CA
California Sportfishing Protection Alliance, Stockton, CA
California Stormwater Quality Association, Menlo Park, CA
California Water Impact Network, Santa Barbara, CA
Jamie Carey
CASA
Central Delta Water Agency, Stockton, CA
Central Valley Clean Water Association
Central Valley Regional Water Quality Control Board, Rancho Cordova, CA
City of Antioch, CA
Clean Water Action, San Francisco, CA
Coalition for a Sustainable Delta, Bakersfield, CA
Congress of the United States, Washington, DC
Contra Costa County, Martinez, CA
Thomas J. Cordano, Sacramento, CA
County of Sacramento
Crisi Matthews Real Estate
Delta Stewardship Council, Sacramento, CA
Discovery Bay Yacht Club
David Ford, Fair Oaks, CA
Environmental Incentives, South Lake Tahoe, CA
Jon A. Hammari, Carmichael, CA
Dr. Irwin Haydock
Larry Ladd
Natural Resources Defense Council
No information provided (2)
Northern California Water Association, Sacramento, CA
Pacific Advocates
Sacramento Regional County Sanitation District, Sacramento, CA
Sacramento Valley Water Quality Coalition, Sacramento, CA
San Francisco Bay Regional Water Quality Control Board, Oakland, CA
San Francisco Estuary Partnership
San Joaquin Exchange Contractors Water Authority, Los Banos, CA
San Joaquin River Group Authority
San Louis & Delta-Mendota Water Authority, Los Banos, CA
SCAP

Seafood Suppliers Inc., San Francisco, CA
Terry Spragg
Robert Stanley, Chico, CA
State Water Contractors, Sacramento, CA
Douglas Stocks, Oroville, CA
Student
The Bay Institute
TriTAC
United States Department of Commerce, Long Beach, CA
United States Department of the Interior, Sacramento, CA
University of Nevada, Reno, NV
Valley Permit Services
Western Plan Health Association, Sacramento, CA
Western States Petroleum Association
Westlands Water District, Fresno, CA

Attachment 2 of Final Report

DRAFT

Review of Scientific Papers and Summary of Key Findings

For the ASC-EPA Technical Workshop on
Estuarine Habitat in the Bay Delta Estuary

Prepared for
U.S. Environmental Protection Agency
March 2012

Thomas Jabusch
Aquatic Science Center

Building a Common Library of Scientific Papers

This document summarizes the key findings of selected technical papers on X2, the low salinity zone, and the ecological community of the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay Delta Estuary). The Aquatic Science Center (ASC) prepared the summary to support the technical workshop on estuarine habitat being staged in Sacramento on 27 March 2012 by ASC and EPA. This summary is accompanied by a common library of online scientific papers that workshop participants will be able to access before, during, and after the workshop. ASC analyzed papers in this library to identify common themes, key points of agreement and disagreement (and reasons thereof), and uncertainties.

The common library was built through a relatively informal process. As a starting point, Dr. Bruce Herbold offered an initial list of thirty-six (36) "essential" LSZ/X2 papers produced since 1995. This became known as the "long-list" of papers that provided a useful reference tool to subsequent reviewers of the list. Based on the long-list, Dr. Wim Kimmerer kindly suggested a shorter, more manageable set of papers, and this became known as the "short list." Dr. Kimmerer used the following criteria for selecting a paper for the short list: the paper (1) applies in particular to the low-salinity zone, or to species resident there; and (2) either provides a good overview of the habitat, or provides new looks at particular aspects of that habitat.

Drs. Anke Mueller-Solger and Matt Nobriga graciously reviewed both lists and added their own recommendations. Each scientist arrived at a slightly different list of essential papers, and all agreed that the task was difficult and depended upon the selection criteria for inclusion. Given time constraints, prospective workshop participants were not surveyed about the selection criteria, and ASC and EPA were willing to accept the basic criteria established by Dr. Kimmerer and the collective, best professional judgment of Drs. Herbold, Mueller-Solger, and Nobriga. The final list of 23 papers provided here represents a hybrid of the "desert island" lists that were provided by each expert. The workshop planning team[188] accepted these papers as those most likely to garner the greatest acceptance among workshop participants for their characterization of ecological processes and hydrodynamics pertaining to X2 and the low salinity zone.

[188] Members of the Planning Team for the Estuarine Workshop
Brock B. Bernstein, Ph.D., workshop facilitator under contract with Aquatic Science Center
Erin Foresman, Environmental Scientist & Policy Coordinator, EPA Region 9
Bruce Herbold, Ph.D., EPA Region 9
Thomas Jabusch, Ph.D., Aquatic Science Center
Tim Vendlinski, Senior Policy Advisor, EPA Region 9

Summary of Key Findings

There are well-accepted statistical relationships between the abundance and survival of fishes and other estuarine species with the location of the low salinity zone (LSZ), as represented by X2 (the 2% bottom salinity position). However, there is a need to more extensively study causal relationships among X2, estuarine habitat quality, and fish populations.

Agreements

The following statements represent general consensus of the science community, as represented in the peer-reviewed literature pertaining to the LSZ or X2:

Habitat

Abundance of Zooplankton and Young Fishes is Centered Near or Slightly Upstream of the LSZ. Bennett et al. (2002), Jassby et al. (1995), Kimmerer et al. (2002), Moyle et al. (1992).

Low Salinity Habitat Distributed Over Shoal Areas Is More Productive and Provides Better Rearing Conditions Than Habitat Confined to Deeper Channels. Overall, the historical sampling record indicates that delta smelt have remained several fold more abundant in northern Suisun Bay and Suisun Marsh channels than in southern Suisun Bay and the Delta. There also appears to be a link between the recruitment success for delta smelt and the availability of shallow-water habitats rather than the amount of freshwater outflow alone (as indexed by X2). Bennett (2005), Bennett et al. (2002), Moyle et al. (1992).

Delta Smelt Habitat Extent. Delta smelt is endemic to the estuary; habitat extends from the tidal freshwater reaches of the Delta seaward to about 19 psu salinity at water temperatures lower than 25°C. Bennett (2005).

Habitat for Northern Anchovy Is Negatively Related to X2. When the Asian clam *Corbula amurensis* invaded the San Francisco Estuary in 1986, the distribution of northern anchovy (*Engraulis mordax*), the most common fish in the estuary, shifted toward higher salinity, reducing summer abundance in the LSZ by 94%. The response of the anchovy to the arrival of *Corbula* was rapid, manifested in a sharp decline in summer abundance from 1986 to 1987. The resulting shift in the anchovy's spatial distribution in the estuary appears to have been a direct behavioral response to reduced food (i.e., reduction in overall biomass and replacement of preferred zooplankton species by invasives, as indicated by carbon biomass estimates). Although the abundance of northern anchovy has declined in the low salinity zone, it still dominates the biomass of fish in the more saline reaches of the estuary. The bulk of the anchovy population even before the decline was at high salinity: 95% of the catch before 1987 occurred at salinities greater than 10%. Kimmerer (2006).

Fish Populations

Pelagic Organism Decline (POD): Populations of Four Pelagic Fishes

Suddenly Declined in the Early 2000s. Change point models detected step declines in abundances of delta smelt, longfin smelt, striped bass, and threadfin shad in the early 2000s, with a likely common decline in 2002. However, no single factor emerged to explain the POD (see Uncertainties), which is now believed to be the result of multiple effects. Abiotic habitat factors relate directly and indirectly to the declining fish Abundances. The conclusion is based on univariate and multivariate analyses of the effects of abiotic habitat variables, in particular X2 and water clarity. Abiotic habitat factors can affect fish by directly increasing or decreasing the extent of their physical habitat and indirectly by impacting their prey or predators. Bennett (2005), Mac Nally et al. (2010), Thomson et al. (2011).

Delta Smelt and Striped Bass Are More Abundant in More Turbid Waters. Based on generalized additive modeling results, the predicted occurrence of delta smelt and striped bass decreased as Secchi depth increased. Feyrer et al. (2007).

Young Fishes And Zooplankton Can Actively Maintain Position Within the LSZ. Young fishes migrated vertically and maintained position in the LSZ, switching between two strategies depending on freshwater flow and longitudinal position of the LSZ. Zooplankton in the LSZ also migrates vertically with the tides to maintain position, but there are differences among years and between taxa. Bennett et al. (2002), Kimmerer et al. (1998), Kimmerer et al. (2002).

For Delta Smelt, Fall Stock Abundance and Fall Water Quality Affect Recruit Abundance the Following Summer. Based on generalized additive modeling results, the combined effects of fall stock abundance and water quality (i.e., salinity and water clarity), predicted recruitment abundance in the following summer, at least during the past two decades, when food availability was severely reduced by *Corbula*. Feyrer et al. (2007), Nobriga et al. (2008).

Flow Response

The Abundance of Several Common Species of Fish Varies Positively With Flow Entering the Estuary, as Indexed by X2. Based on data collected through 1992, Jassby et al. (1995) presented simple and significant statistical relationships of X2 with annual measures of phytoplankton-derived detritus from river loading; mollusks; mysids (*Neomysis mercedis*); bay shrimp (*Crangon franciscorum*); larval fish survival; and the abundance of longfin smelt (planktivorous), striped bass (piscivorous), and starry flounder (bottom-foraging). The abundance of most of these fish and the shrimp species is elevated in years when mean spring and early summer (April – July) X2 locations are moved seaward (closer to the Golden Gate) by high Delta outflows. The starry flounder abundance index responds to spring X2 in the previous year.

There are also notable exceptions. For example, delta smelt abundance does not correspond to X2 (see: Uncertainties).

Adding 7 to 8 yr of post-*Corbula* data (based on availability) to those previously analyzed by Jassby et al. (1995), Kimmerer (2002) found that most of the species that were responsive to flow before *Corbula*'s arrival continue to have statistically demonstrable linkages between abundance or early life stage survival and X2 position. Kimmerer's analyses confirmed that all of the fish and shrimp, except delta smelt, had negative relationships with X2, indicating higher abundance at high flow. Two of them, starry flounder and longfin smelt, had negative relationships with X2 with no significant change in slope before and after 1987 but with lower intercepts after 1987, indicating 4-fold declines in overall abundances after the arrival of *Corbula*. The bay shrimp *Crangon franciscorum* had a significant relationship with X2 that had not appeared to change since 1988, although both the lowest and highest residuals around the X2 trend line were observed after 1988, indicating a possible transient response either to the change in the food web or to the extended drought from 1985 to 1992. An exception to this overall trend of continuity was the response of the mysid shrimp *Neomysis mercedis*, which was previously abundant in the LSZ in summer but declined about 50-fold after 1987. The response of *N. mercedis* to X2 changed significantly between the two periods, with a negative slope through 1987 (higher at high flow) and a steep positive slope thereafter (higher at low flow).

Although X2 is not equivalent to flow, it still reflects the large interannual variability in river flow. Daily, monthly, and seasonal time series regressions demonstrate strong relationships between X2 and Delta outflow. $X2 \sim Q^{1/7}$, based on more than 20 years of data in which flow varies by a factor of approximately 200.

Jassby et al. (1995), Kimmerer (2002), Monismith et al. (2002), Moyle et al. (1992), Nobriga et al. (2008).

Organic Carbon Supply Increases With Flow. The supply rate of organic carbon to the Estuary increases with increasing freshwater flow, mainly because of river-borne inputs. However, much of the organic carbon in wet years is wood and thus less bio-active. Herbold (pers. comm.), Jassby et al. (1995).

Foodweb

***Corbula* Caused a Major Change in the Food Web.** Chlorophyll a and several species of zooplankton (including mysids and some copepods) declined markedly after 1987. Mysids declined by about half and declines in some copepod species were accompanied by increases in other, introduced species. These introduced species are of lower nutritional value (e.g. omega fatty acid content). The now dominant exotic copepod *Limnoithona tetraspina*, is also much smaller than the species it replaced, requiring planktivores to "work harder" to capture equivalent quantities of food. Bennett (2005), Herbold (pers. comm.), Kimmerer (2002), Kimmerer (2006).

Productivity[189]

[189] In this context, the difference between productivity and biomass should be considered. For example, ammonium (NH_4) may decrease primary productivity by inhibiting algal growth (Dugdale et al. 2007), presumably resulting in a decrease in biomass. On the other hand, clams are believed to largely redirect productivity from the pelagic to the benthic foodweb. In theory, the result should be no overall change in biomass (assuming that differences between the pelagic and benthic pathways in the efficiency of energy transfer from one trophic level to the next are negligible). However, grazing by clams may also deplete populations of phytoplankton to the point

Loss of Diatom Production. After *Corbula* arrived, a decline in the proportion of diatoms was observed in the phytoplankton of the upper estuary. Kimmerer (2005).

Low Salinity Zone

The Salinity Field Embodies Information Not Directly Or Solely Related to the Chemical Properties of Water. The amount of freshwater flow into the Estuary is reflected in the salinity distribution, which in turn may determine the geographic location of estuarine turbidity maxima, entrapment phenomena, or null zones. For example, variation in gravitational circulation at a longer time scale may occur due to movement of the LSZ in response to variation in freshwater flow. Jassby et al. (1995), Peterson et al. (1975).

In Spring and Summer, the LSZ Forms Multiple Estuarine Turbidity Maxima of Various Origins. In the varying bathymetry of northern San Francisco Bay, the LSZ can move between shallow and deep water, altering the propensity for gravitational circulation to occur and producing multiple ETMs that are positioned by bottom topography instead of salinity. Schoellhamer (2001).

Gravitational Circulation Is Frequent in Deeper Water. Stratification and gravitational circulation are dependent on depth and more frequently observed in the deeper water column of Carquinez Strait, compared to shallower areas. Bennett et al. (2002), Kimmerer et al. (2002).

Models

Habitat Volume is Highly Correlated With Surface Area. Kimmerer et al. (2009) simulated habitat volume using the TRIM3D hydrodynamic model and found that slopes of habitat volume vs. X2 were highly correlated with slopes of habitat area vs. X2 ($r^2 = 0.97$). Feyrer et al. (2011), Kimmerer et al. (2009).

Disagreements

Habitat

Examining and Predicting Habitat Use. Both Kimmerer et al. (2009) and Feyrer et al. (2011) employed General Additive Modeling (GAM) to predict habitat use by estuarine fish. Kimmerer et al. (2009) employed habitat curves based on catch per trawl, because they were usually closer to the underlying fish distributions than those based on frequency of occurrence, which they argue tended to be extremely skewed. Feyrer et al (2011) chose to model frequency of occurrence rather than catch per trawl, as they argue, to minimize the possible influence of outliers and bias associated with long-term abundance declines. Feyrer et al. (2011), Kimmerer et al. (2009).

Productivity

---

where primary productivity is getting reduced.

Lack of Phytoplankton Blooms in the Upper Estuary. In contrast to many estuarine systems, phytoplankton blooms are rare in the Estuary although nutrient concentrations are high. This has been attributed to several causes including high turbidity, high ammonium concentrations, and grazing by *Corbula*. Alpine and Cloern (1992), Dugdale et al. (2007).

Decline in Phytoplankton Biomass. Since the mid-1970s, the upper Estuary had experienced declines in phytoplankton biomass, zooplankton abundance, and fish populations. The downward trend in phytoplankton biomass over the last few decades is combined with "demographic" changes in the phytoplankton community from large diatoms to flagellates, blue-green algae, and smaller species of diatoms. The drivers of the algal trends are still being debated. The large decline in phytoplankton biomass (as measured by chlorophyll a) in Suisun Bay occurred mostly after the introduction of *Corbula* in 1986, but several other drivers are thought to play a role in the observed changes to the algal community. Among them are increased ammonia loadings, water diversions, and a reduction in phosphorus loadings. Earlier observations that phytoplankton has rebounded in the Delta in the late 90s seem to be confounded by more recent data indicating a continuation of the long-term decline. Baxter et al. (2010), Bennett and Moyle (1996), Brown (2009), Jassby (2008), Jassby et al. (2002), Kimmerer (2002), Van Nieuwenhuyse (2007), Winder & Jassby (2010).

Uncertainties

Habitat

Use of Abiotic Habitat Variables for Management Purposes. The habitat value of the LSZ for young fishes and other planktonic organisms may be enhanced by increased Delta outflows. Recent results have highlighted the importance of other abiotic variables, including water clarity and water temperatures. However, salinity, water clarity, and temperature don't fully define abiotic habitat. Additional information is needed to better define the mechanisms that mediate the effects of water quality variables on aquatic organisms. This also requires a more complete understanding of how the direct effects of water exports interact with the indirect effect of affecting abiotic conditions and the food web. Bennett (2005), Feyrer et al. (2007); Jassby et al. (1995), Kimmerer (2002), Kimmerer et al. (2009), Nobriga et al. (2008), Mac Nally et al. (2010).

Future Habitat Conditions. Habitat suitability is sensitive to system changes. However, there is high uncertainty about future trends in factors that are likely to influence habitat suitability, such as future precipitation, catastrophic natural events, or future policy directions. Feyrer et al. (2007), Nobriga et al. (2008).

Mechanisms That Affect the Nursery Habitat Potential of the LSZ. The LSZ is presumably an essential estuarine nursery habitat, a role implied in numerous findings, including the influence of salinity on the geographic distribution of young delta smelt. Moreover, various fish larvae exhibit complex behavior to locate and maintain position in or relative to the LSZ. However, causal relationships between the hydrodynamics of the LSZ and the abundance and distribution of young fishes remain largely unresolved. Jassby et al. (1995), Nobriga et al. (2008).

Relationship of X2 to Delta Smelt Abundance. There is a lack of correspondence between delta smelt abundance and X2 position or habitat volume in the upper estuary. Despite its distribution within the LSZ, delta smelt abundance has not responded predictably to interannual river flow variation and the location of X2. In several recent years (since 1993), adult abundance remained fairly low even though X2 frequently was located in Suisun Bay. Regressions on delta smelt abundance index data from 1975 – 1999 for two time periods (1975 – 1981 and 1981 – 1999) showed a positive relationship with X2 during the period up to 1981 and a negative but non-significant relationship from 1982 on. Bennett (2005) notes that the abundance of delta smelt is elevated only in years when the low salinity zone is located in Suisun Bay; and, from an ecosystem perspective, the abundances of a variety of organisms are enhanced with X2 in Suisun Bay. Nobriga et al. (2008) suggest that the relationship between X2 and delta smelt abundance at the population level is not apparent, because the effects occur seasonally, and at spatial scales smaller than the entire upper San Francisco Estuary. They found that salinity predicted delta smelt occurrence in three distinct geographic regions (Suisun Bay, Sacramento-San Joaquin River confluence, and San Joaquin Delta) that had similar long-term trends in delta smelt capture probabilities. Bennett (2005), Jassby et al. (1995), Kimmerer (2002), Kimmerer et al. (2009), Nobriga et al. (2008).

Delta Smelt Habitat Suitability. There is evidence that suitable abiotic habitat for delta smelt is determined mainly by two factors, salinity and turbidity. Water temperature may also play an important role, since it can constrain delta smelt in the summer. Many other potential factors may affect delta smelt habitat suitability, including food density, entrainment risk, predation risk, or exposure to contaminants. Data on such factors are limited. Interactions between abiotic and biotic habitat components can affect vital rates (per capita birth, death, fecundity) and exert density-dependent effects on population dynamics, although such relationships are currently poorly understood. Bennett (2005), Feyrer et al. (2007), Feyrer et al. (2011), Mac Nally (2010).

Role of Macrophyte Proliferation. The invasion of aquatic macrophytes has already substantially changed near-shore fish assemblages and may also have restricted pelagic fish distributions. In particular, the invasive Brazilian waterweed (*Egeria densa*) increases water clarity by trapping suspended sediments, thus negatively affecting native and desirable pelagic fishes. Feyrer et al. (2007), Nobriga et al. (2008).

Flow Response

Mechanisms Underlying Fish Abundance Responses to Flow. Longfin smelt appears to have the strongest relationship with X2. For other pelagic fishes, the relationship of abundance with X2 is weaker than for longfin smelt and is affected by other factors. Kimmerer et al (2009) calculated a habitat index based on 3-D modeling of LSZ habitat volume, weighted by resource selection functions for eight species. Slopes of these habitat indices vs. flow were consistent with slopes of abundance vs. flow for only two of the eight species examined. The authors conclude that mechanisms other than variation in physical habitat must underlie responses of abundance to flow for most species. Jassby et al. (1995), Kimmerer (2002), Kimmerer et al. (2009), Thomson et al. (2010).

Fish Populations

Mechanisms Causing Fish Declines. Species-by-species models and statistical analyses to identify mechanisms causing fish declines suggest that several abiotic factors (e.g., water flows, salinity, turbidity, temperature), bottom-up biotic effects (e.g., zooplankton abundances, invasion of *Corbula*), and top-down factors (e.g., incidental mortality associated with water diversions to pumping facilities) may play important roles. Multivariate autoregressive modeling (MAR) is a new tool that can be applied for simultaneous modeling of multiples species and interactions among species and covariates. MAR was used to identify increased upstream position of X2 and increased water clarity as two main factors negatively affecting multiple declining taxa, including fishes and their main zooplankton prey. Bennett (2005), Feyrer et al. (2007), Jassby et al. (1995), Mac Nally et al. (2010).

Vertical and Horizontal Distribution Patterns of Zooplankton and Fishes. There are differences among years and variability among taxa in the tidal movements of zooplankton and fishes in the LSZ that are not fully explained. The migratory behavior of copepods is not consistent with, but also not responsive to, changes in freshwater flow, salinity, or stratification. In the Suisun Bay ship channel, most fishes and zooplankton appeared to undergo tidal vertical migrations, occurring near the surface during flood tides and at depth on ebbs. However, in Suisun Cut some fishes, including delta smelt, appeared to undergo reverse diel migrations, remaining near the surface during the day and at depth during the night. Delta smelt post-larvae in freshwater portions of the Sacramento and San Joaquin rivers were significantly more abundant at depth during the day relative to night, but the results are difficult to interpret without accompanying hydrodynamic information. The mechanisms responsible for variability in migration behaviors remains unclear as are the potential benefits gained by maintaining position in the LSZ. Bennett et al. (2002), Kimmerer (2002), Kimmerer et al. (2002), Bennett (2005).

Delta Smelt Population Dynamics. Bennett's population viability analysis suggests the delta smelt is at risk of extinction. Limited distribution, short life span, low reproductive capacity, as well as relatively strict abiotic habitat and feeding requirements, are indications that delta smelt is at catastrophic risk in a fluctuating environment. A small percentage (<10%) lives two years and may have an important influence on population dynamics by augmenting spawning success after years of poor recruitment. Bennett (2005).

Significance of the Northern Anchovy's Disappearance From the LSZ For Other Fishes. The disappearance of the northern anchovy from the LSZ may have allowed more successful foraging of remaining species, especially delta smelt and longfin smelt. Northern anchovy is a filter feeder, food density-dependent feeder and thus may be more sensitive to changes in the abundance of their prey than smelt, which are "picking type" of feeders whose feeding success is more of a density independent, or density vague process. Bennett (2005)

Short List of Key Papers on X2 and the Low Salinity Zone since 1995

1995

1. Jassby AD, Kimmerer WJ, Monismith SG, Armor C, Cloern JE, Powell TM, Schubel JR, Vendlinski TJ. 1995. Isohaline position as a habitat indicator for estuarine applications. Ecological Applications 5(1): 272-289.

2001

2. Schoellhamer, DH. 2001. Influence of salinity, bottom topography, and tides on locations of estuarine turbidity maxima in northern San Francisco Bay. Coastal and Estuarine Fine Sediment Processes. Elsevier, Amsterdam, The Netherlands.

2002

3: Kimmerer WJ, Bennett, WA, Burau JR. 2002. Persistence of tidally-oriented vertical migration by zooplankton in a temperate estuary. Estuaries 25: 359-371.

4: Bennett WA, Kimmerer WJ, Burau JR. 2002. Plasticity in vertical migration by native and exotic estuarine fishes in a dynamic low-salinity zone. Limnology and Oceanography 47: 1496-1507.

5: Monismith SG, Kimmerer WJ, Burau JR, Stacey MT. 2002. Structure and flow-induced variability of the subtidal salinity field in northern San Francisco Bay. Journal of Physical Oceanography 32: 3003-3019.

6: Kimmerer WJ. 2002. Effects of freshwater flow on abundance of estuarine organisms: physical effects or trophic linkages? Marine Ecology and Progress Series 243: 39-55.

2004

7: Ruhl CA, Schoellhamer DH. 2004. Spatial and temporal variability of suspended-sediment concentrations in a shallow estuarine environment. San Francisco Estuary and Watershed Science 2(2): 1.

2005

8: Kimmerer WJ. (2005. Long-term changes in apparent uptake of silica in the San Francisco estuary. Limnology and Oceanography 50: 793-798.

9: Bennett WA. 2005. Critical assessment of the delta smelt population in the San Francisco Estuary, California. San Francisco Estuary and Watershed Science 3(2): 1.

2006

10: Hobbs JA, Bennett WA, Burton JE. 2006. Assessing nursery habitat quality for native smelts (*Osmeridae*) in the low-salinity zone of the San Francisco Estuary. Journal of Fish Biology 69: 907-922.

11: Kimmerer WJ. 2006. Response of anchovies dampens effects of the invasive bivalve Corbula amurensis on the San Francisco Estuary foodweb. Marine Ecology Progress Series 324: 207-218.

2007

12: Dugdale RC, Wilkerson FP, Hogue VE, Marchi A. 2007. The role of ammonium and nitrate in spring bloom development in San Francisco Bay. Estuarine, Coastal and Shelf Science 73(1-2): 17-29.

13: Feyrer F, Nobriga ML, Sommer TR. 2007. Multi-decadal trends for three declining fish species: habitat patterns and mechanisms in the San Francisco Estuary, California, USA. Canadian Journal of Fisheries and Aquatic Sciences 64(4): 723-734.

2008

14: Nobriga M, Sommer T, Feyrer F, Fleming K. 2008. Long-term trends in summertime habitat suitability for delta smelt, *Hypomesus transpacificus*. San Francisco Estuary and Watershed Science 6(1): 1.

15: Jassby AD. 2008. Phytoplankton in the Upper San Francisco Estuary: recent biomass trends, their causes and their trophic significance. San Francisco Estuary and Watershed Science 6(1): 2.

2009

16: Kimmerer WJ, Gross ES, MacWilliams ML. 2009. Is the response of estuarine nekton to freshwater flow in the San Francisco Estuary explained by variation in habitat volume? Estuaries and Coasts 32: 375-389.

17: Enright C, Culberson SD. 2009. Salinity trends, variability, and control in the northern reach of the San Francisco Estuary. San Francisco Estuary and Watershed Science, 7(2): 3.

2010

18: Mac Nally R, Thomson JR, Kimmerer WJ, Feyrer F, Newman KB, Sih A, Bennett WA, Brown L, Fleishman E, Culberson SD, Castillo G. 2010. An analysis of pelagic species decline in the upper San Francisco Estuary using multivariate autoregressive modeling. Ecological Applications 20(5): 1417-1430.

19: Thomson JR, Kimmerer WJ, Brown LR, Newman KB, Mac Nally R, Bennett WA, Feyrer F, Fleishman E. 2010. Bayesian change point analysis of abundance trends for pelagic fishes in the upper San Francisco Estuary. Ecological Applications 20(5): 1431-1448.

2011

20: Feyrer F, Newman K, Nobriga M, Sommer T. 2011. Modeling the effects of future outflow on the abiotic habitat of an imperiled estuarine fish. Estuaries and Coasts 34: 120-128.

21: York J, Costas B, McManus G. 2010. Microzooplankton grazing in green water—results from two contrasting estuaries. Estuaries and Coasts 34: 373-385.

22: Winder M, Jassby AD. 2011. Shifts in zooplankton community structure: implications for food web processes in the upper San Francisco Estuary. Estuaries and Coasts 34: 675-690.

23: Schoellhamer DH. 2011. Sudden clearing of estuarine waters upon crossing the threshold from transport to supply regulation of sediment transport as an erodible sediment pool is depleted: San Francisco Bay, 1999. Estuaries and Coasts 34: 885-899

Summaries

1: Isohaline position as a habitat indicator for estuarine populations
Author(s): A. D. Jassby, W. J. Kimmerer, S. G. Monismith, C. Armor, J. E. Cloern, T. M. Powell, J. R. Schubel, and T. J. Vendlinski
Year: 1995
Journal: Ecological Applications
Volume: 5
Number: 1
Pages: 272-289
URL: http://sfbay.wr.usgs.gov/publications/pdf/jassby_1995_isohaline.pdf
Relevance to X2 and LSZ: This paper reports the scientific basis of using X2 (the 2% bottom salinity position) as a habitat indicator to regulate freshwater flow to the Bay Delta Estuary. Participants in EPA's initial estuarine habitat workshop recommended that standards for protecting aquatic life should be based at least in part on the estuary's physical response to fluctuations in freshwater input, i.e., on some "habitat indicator" (sensu Messer 1990, who defines habitat indicator as a "physical attribute measured to characterize conditions necessary to support an organism, population, or community in the absence of pollutants"). The salinity field was of particular interest, and X2 was found to be particularly valuable because by knowing X2 only, one can recreate the entire mean salt field in the Estuary. Additional advantages include that it can be measured with greater accuracy and precision then net freshwater inflow into the estuary. At the same time, statistical analyses demonstrate an unambiguous relationship of X2 with net Delta outflow. The recommendation for X2 as a habitat indicator are based on statistical relationships with year-to-year variability in multiple estuarine resources, including phytoplankton, mollusks, and fish. In the case of fish, clear and pervasive relationships are demonstrated with bottom-foraging fish (starry flounder) and both survival (striped bass) and abundance (longfin smelt and striped bass) of fish that feed in the water column. There is also a clear and pervasive relationship between X2 and phytoplankton-derived particulate organic carbon (POC). The response of the mollusk community is more distinctive. The mollusk abundance index, expressed as the total mollusk density in Grizzly Bay, showed a clear minimum at intermediate values of X2.

2: Influence of salinity, bottom topography, and tides on locations of estuarine turbidity maxima in northern San Francisco Bay
Author(s): D. H. Schoellhamer
Year: 2001
Book: Coastal and Estuarine Fine Sediment Processes
Editor(s): W. H. McAnally and A. J. Mehta
Publisher: Elsevier, Amsterdam, Netherlands
Pages: 373-385
URL: http://sfbay.wr.usgs.gov/sediment/elsevierPDF.html
Relevance to X2 and LSZ: The purpose of this paper is to describe how salinity, bottom topography, and tides influence the locations of the estuarine turbidity maximum (ETM), or suspended sediment concentration (SSC) maxima, in northern San Francisco Bay. ETMs form when salinity is present but they are not associated with a singular salinity. In San Francisco Bay, there is a larger salinity range for ETM location than is observed in other estuaries. The processes that account for a salinity-dependent ETM include gravitational circulation, salinity stratification, and bed storage. The longitudinal salinity gradient, not salinity, creates gravitational circulation and ETMs. All these processes occur in northern San Francisco Bay and are modified by bottom topography and tides. Bottom topography enhances salinity stratification, gravitational circulation, and ETM formation seaward of sills. Salinity stratification in Carquinez Strait, which is seaward of a

sill, is greatest during neap tides, which are the only times when tidally averaged SSC in Carquinez Strait was less than that observed landward at Mallard Island. Maximum bottom SSC measured by USGS water quality cruises was located in Carquinez Strait 67 percent of the time, and tidally averaged SSC was greater in Carquinez Strait and the Reserve Fleet Channel, which are both seaward of sills, compared with more landward sites.

3: Persistence of tidally oriented vertical migration by zooplankton in a temperate estuary
Author(s): W. J. Kimmerer, W. A. Bennett, and J. R. Burau
Year: 2002
Journal: Estuaries
Volume: 25
Number: 3
Pages: 359-371
URL: http://www.springerlink.com/content/g55tp2lx7x3r5v66/fulltext.pdf
Relevance to X2 and LSZ: Results from this study show differences among years and variability among taxa in the tidal movements of zooplankton species in the LSZ. The authors demonstrate extensive evidence showing some degree of persistence of various behaviors but were unable to determine how these translate to position maintenance. Based on the presented results, the variable bathymetry in the northern Estuary may play a key role in position maintenance. The migratory behavior of copepods was not consistent and also not responsive to changes in freshwater flow, salinity, or stratification. By contrast, mysids and amphipods responded to freshwater flow regimes. The results for copepods suggest rigid behavior regardless of changing environmental variables, whereas mysids and amphipods altered their behavior depending on local conditions related to freshwater flow. The zooplankton species differed in salinity range. The authors also observed a landward shift of the center of abundance of the copepod *Eurytemora affinis*, which appears to have coincided with the spread of the introduced clam *Potamocorbula amurensis*. They also determined that, since 1988, chlorophyll concentration has been lower in the LSZ compared to the freshwater Delta. During 1988-1998, chlorophyll was generally about 3-fold to 10-fold lower than previously for salinity values between 0.5 and 20 psu, and a consistent and occasionally steep spatial gradient was observed with higher chlorophyll at salinity values below 1 psu.

4: Plasticity in vertical migration by native and exotic estuarine fishes in a dynamic low-salinity zone
Author(s): W. A. Bennett, W. J. Kimmerer, and J. R. Burau
Year: 2002
Journal: Limnology and Oceanography
Volume: 47
Number: 5
Pages: 1496-1507
URL: http://www.aslo.org/lo/toc/vol_47/issue_5/1496.html
Relevance to X2 and LSZ: This paper examines the degree of flexibility in retention strategies of young fishes in the LSZ during years of highly variable river flow. Young fishes migrated vertically and maintained position in the LSZ, switching between two strategies depending on freshwater flow and longitudinal position of the LSZ. Abundances of four fish species (delta smelt, longfin smelt, striped bass, yellowfin goby) and estimated volume of detrital material were highest at the lower end of the range of salinity sampled in the LSZ. These results support previous observations (see, for example Moyle et al. 1992) showing that an assemblage of young fishes occupies the turbid landward margin of the LSZ. In 1994, striped bass, longfin smelt, and yellowfin goby migrated tidally, occurring near the surface on flood tides and near the bottom on ebb tides. During 1995, this behavior persisted for striped bass and yellowfin goby, even though landward residual currents

were present under high river-flow conditions. In contrast, during moderate freshwater flow conditions when the LSZ was positioned in the morphologically complex central Suisun Bay, fishes exhibited reverse diel migrations at the north channel sites such that they were more abundant at the surface by day and at depth by night. The authors suggest that vertical migrations may enhance feeding success, because zooplankton prey similarly migrated in the LSZ.

5: Structure and flow-Induced variability of the subtidal salinity field in northern San Francisco Bay
Author(s): S. G. Monismith, W. J. Kimmerer, J. R. Burau, and M. T. Stacey
Year: 2002
Journal: Journal of Physical Oceanography
Volume: 32
Pages: 3003-3019
URL: http://www-ce.stanford.edu/faculty/monismith/MonismithEtAl2002JPO.pdf
Relevance to X2 and LSZ: This paper provides new insights into the salinity distribution (geographically and over time) of the estuary as it relates to X2. It discusses the structure of the salinity field in northern San Francisco Bay and how it is affected by freshwater flow. Analysis of covariability of Q and X showed a characteristic timescale of adjustment of the salinity field of approximately 2 weeks in response to flow. X2 was found to be proportional to riverflow to the 1/7 power. Thus, the (geographical) length of salinity intrusion into the northern estuary turns out to be relatively insensitive to river flow. The authors argue that the relatively weak dependence of salinity intrusion on flow is owed to dynamic tidal variations, which modulate stratification in the northern estuary. Regardless, they find that X2 can be used as an unambiguous flow-dependent length (as in "distance") scale for salinity intrusion, based on the relationship of $X2 \sim Q^{1/7}$. A key finding from the analysis is a self-similar distribution (whole curve has similar shape as it parts) of depth-averaged salinity in the estuary that is proportional to 1/X2, with a salinity gradient in the center 70% of the region between the Golden Gate and X2. For improving vertically resolved models of salinity intrusion (circulation models), accurately modeling the effects of stratification may be key.

6: Effects of freshwater flow on abundance of estuarine organisms: physical effects or trophic linkages?
Author(s): W. J. Kimmerer
Year: 2002
Journal: Marine Ecology Progress Series
Volume: 243
Pages: 39-55
URL: http://www.waterrights.ca.gov/baydelta/docs/exhibits/DOI-EXH-33I.pdf
Relevance to X2 and LSZ: Kimmerer posits that variations in the abundance or survival of fish in the northern estuary may occur through attributes of physical habitat that vary with flow. Based on reexamining responses of estuarine species to flow and changes in the foodweb (caused by the invasion of *Potamocorbula amurensis*), he concludes variation with freshwater flow of abundance or survival of organisms in higher trophic levels apparently did not occur through upward trophic transfer. All but 3 of the examined species had median salinity between 0.5 and 6, i.e. their distributions overlapped substantially with the LSZ, but large parts of their populations are outside of the LSZ. Fish (with the exception of delta smelt) and shrimp responded positively to flow, whereas chl a (i.e., phytoplankton) and several species of zooplankton had either weak responses to flow or responses that changed after the arrival of *P. amurensis* in 1987. Following the spread of *P. amurensis,* there is a marked decreasing trend in organic matter production and plankton abundance with time, but fish and shrimp did not appear to respond to this change.

7: Spatial and temporal variability of suspended sediment concentrations in a shallow estuarine environment

Author(s): C. A. Ruhl and D. H. Schoellhamer
Year: 2004
Journal: San Francisco Estuary and Watershed Science
Volume: 2
Number: 2
Pages: Article 1
URL: http://escholarship.org/uc/item/1g1756dw#page-1
Relevance to X2 and LSZ: Sediment transport shallow water differs from that in deeper channels because of greater wind wave resuspension, closer proximity to the shore and tributaries, and greater relative benthic filtering. The U.S. Geological Survey measured suspended-sediment concentrations at five locations in Honker Bay, a shallow subembayment of San Francisco Bay, and the adjacent channel to investigate the spatial and temporal differences between deep and shallow estuarine environments. During the first freshwater pulse of the wet season, the channel tended to transport suspended sediments through the system, whereas the shallow area acted as off-channel storage where deposition would likely occur. Following the freshwater pulse, suspended-sediment concentrations were greater in Honker Bay than in the adjacent deep channel, due to the larger supply of erodible sediment on the bed. However, the tidal variability of suspended-sediment concentrations in both Honker Bay and in the adjacent channel was greater after the freshwater pulse than before. During wind events, suspended-sediment concentrations in the channel were not affected; however, wind played a crucial role in the resuspension of sediments in the shallows.

8: Long-term changes in apparent uptake of silica in the San Francisco Estuary
Author(s): W. J. Kimmerer
Year: 2005
Journal: Limnology and Oceanography
Volume: 50
Number: 3
Pages: 793-798
URL: http://www.aslo.org/lo/toc/vol_50/issue_3/0793.html
Relevance to X2 and LSZ: Kimmerer used silica distributions in the northern estuary to infer the apparent uptake of silica and diatom production. Primary production estimated from dissolved silica uptake was similar to production estimated from light and chlorophyll. Production based on dissolved silica (Si_d) averaged 1% and 17% of values prior to the introduction of *P. amurensis*. The Si uptake rates are calculated with a steady-state flux model based on measured salinity gradients and calculated hydraulic residence times. Mixing curves validate the Si-salinity relationship over a range of flow conditions but indicate a slightly negative trend in flow, particularly in June, reflecting the declining hydrograph in the transition from the spring high-flow period to the dry season. However, there is no evidence for an influence of either freshwater flow or temperature, and therefore climate change, on the long-term trend in diatom production.

9: Critical assessment of the delta smelt population in the San Francisco Estuary, California
Author(s): W. A. Bennett
Year: 2005
Journal: San Francisco Estuary and Watershed Science
Volume: 3
Number: 2
Pages: Article 1
URL: http://escholarship.org/uc/item/0725n5vk
Relevance to X2 and LSZ: Delta smelt was formally abundant in the low-salinity and freshwater habitats of the northeastern San Francisco Estuary but is now listed as threatened under the

Federal and California State Endangered Species Acts. A key area of controversy centers on impacts to delta smelt associated with exporting large volumes of freshwater from the estuary to supply California's significant agricultural and urban water demands. Uncertainties about the impacts of water export operations on the delta smelt population range from limited knowledge of the numbers of larvae lost in exported water, and impacts of predators near the facilities, to the conditions promoting significant entrainment events at all life stages. Use of a population model suggests that water export operations can impact the abundance of post-larval (about 20 mm fork length) delta smelt, but these effects may not reflect on adult abundance due to other processes, such as impacts of toxic chemicals or changes to the estuarine foodweb by exotic species. Limited work to date has not shown a significant impact of toxic chemicals on delta smelt, however, the author sees a real threat considering the rapidly evolving development and use of new pesticides. Impacts due to exotic species are likely, but there are large uncertainties, in part due to the complexity of interference with delta smelt recruitment. In comparison with other fish, delta smelt has a tiny geographic range being confined to a thin margin of low salinity habitat in the estuary. It is a small and primarily annual species but with low fecundity and a protracted spawning season: key traits that are typically associated with a perennial life history strategy. Delta smelt also do not appear to compensate for their limited reproductive capacity by having precocious offspring; their larvae are pelagic. Overall, the population persists by maximizing growth, survival, and reproductive success on an annual basis despite an array of limiting factors that can occur at specific times and locations. However, population viability analysis using delta smelt abundance estimates for the entire data record (1982–2003) suggest a high probability that the population would decline post 2004.

10: Assessing nursery habitat quality for native smelts (*Osmeridae*) in the low-salinity zone of the San Francisco Estuary
Author(s): J. A. Hobbs, W. A. Bennett, and J. E. Burton
Year: 2006
Journal: Journal of Fish Biology
Volume: 609
Pages: 907-922
URL: ftp://ftp.water.ca.gov/DES/BDCP/Hobbs%20Bennet%20et_al%202006.pdf
Relevance to X2 and LSZ: Delta smelt in the north channel of Suisun Bay exhibited higher densities, larger sizes, increased somatic condition, and greater feeding success, compared to the south channel. Longfin smelt exhibited similar densities, size distributions, and feeding success between both channels, but generally showed poorer somatic condition for the south channel, potentially due to energetic costs associated with documented vertical migration behavior. Overall, the physical conditions of the north channel provided superior habitat for both species, while the south channel afforded only marginal habitat for longfin smelt and very poor habitat for delta smelt. Therefore, the north channel of Suisun Bay acts as critical nursery habitat by providing better feeding and growing conditions.

11: Response of anchovies dampens effects of the invasive bivalve *Corbula amurensis* on the San Francisco Estuary foodweb
Author(s): W. J. Kimmerer
Year: 2006
Journal: Marine Ecology Progress Series
Volume: 324
Pages: 207-218
URL: http://www.int-res.com/articles/meps2006/324/m324p207.pdf
Relevance to X2 and LSZ: When *C. amurensis* invaded the San Francisco Estuary, the distribution of northern anchovy *Engraulis mordax* shifted toward higher salinity, reducing summer abundance

by 94% in the low-salinity region of the estuary. The shift in spatial distribution appears to have been a direct behavioral response to reduced food. Bioenergetic calculations showed reduced consumption of zooplankton by all planktivores, including mysids, after *C. amurensis* became abundant, and the anchovy left the low-salinity region of the estuary. This reduced consumption appears to have mitigated effects of the loss of phytoplankton productivity due to increased grazing by the invader, making a greater proportion of the zooplankton productivity available to other fish species.

12: The role of ammonium and nitrate in spring bloom development in San Francisco Bay
Author(s): R. C. Dugdale, F. P. Wilkerson, V. E. Hogue, and A. Marchi
Year: 2007
Journal: Estuarine, Coastal, and Shelf Science
Volume: 73
Pages: 17-29
URL: http://www.usc.edu/org/seagrant/Publications/PDFs/Dugdale_etal2_007.pdf
Relevance to X2 and LSZ: The authors suggest that San Francisco Bay's substantial inventory of nitrate (NO_3) is unavailable to the resident phytoplankton most of the year due to the presence of ammonium (NH_4) at inhibitory concentrations that prevent NO_3 uptake. Detailed analysis of spring blooms in three embayments over 3 years shows a consistent sequence of events that starts with improved irradiance conditions through stabilization of the water column by stratification or reduced tidal activity. Second, NH_4 concentrations are reduced to a critical range, 1 to 4 μmol per liter, through dilution by precipitation and by phytoplankton uptake. Third, the drawdown of NH_4 enables rapid uptake of NO_3 and subsequent increase in chlorophyll.

13: Multidecadal trends for three declining fish species: habitat patterns and mechanisms in the San Francisco Estuary, California, USA
Author(s): F. Feyrer, M. L. Nobriga, and T. R. Sommer
Year: 2007
Journal: Canadian Journal of Fisheries and Aquatic Sciences
Volume: 64
Pages: 723-734
URL: http://www.water.ca.gov/aes/docs/FeyrerNobrigaSommer2007.pdf
Relevance to X2 and LSZ: General additive model (GAM) predictions for delta smelt, striped bass, and threadfin shad, exhibited significant long-term declines in habitat suitability in the estuary, especially in San Pablo Bay and the South Delta. Simple regression models suggest that water quality may be an important factor in the decline of delta smelt, at least during the past two decades, when food availability was severely reduced by the invasion of *C. amurensis*. The findings corroborate previous hypotheses that the area of suitable physical and chemical habitat has played a role in the decline in fish abundance.

14: Long-term trends in summertime habitat suitability for delta smelt, *Hypomesus transpacificus*
Author(s): M. Nobriga, T. Sommer, F. Feyrer, and K. Fleming
Year: 2008
Journal: San Francisco Estuary and Watershed Science
Volume: 6
Number: 1
Pages: Article 1
URL: http://www.water.ca.gov/aes/docs/NobrigaSummerHabitat.pdf
Relevance to X2 and LSZ: The findings from this study support the hypothesis that basic water quality parameters are predictors of delta smelt relative abundance, but only at regional spatial

scales. The authors identified three distinct geographic regions that had similar long-term trends in delta smelt capture probabilities: a primary habitat region centered on the confluence of the Sacramento and San Joaquin rivers and two marginal habitat regions, one centered on Suisun Bay and the other on the San Joaquin River and southern Sacramento-San Joaquin Delta. Three water quality variables— specific conductance (salinity), Secchi depth (clarity), and temperature—measured concurrently with fish catches all interact to influence delta smelt occurrence (distribution) in the upper San Francisco estuary and are thus indicators of abiotic habitat suitability. Long-term associations of water quality variation and relative abundance were most notable on the perimeter of the species' distribution outside of the Confluence region. Delta smelt relative abundance in the Suisun region varied in association with specific conductance, which is a function of river inflow variation. The San Joaquin region had the warmest water temperatures and the highest water clarity, which increased strongly in this region during 1970–2004. Increasing water clarity, as the authors suggest, is a long-term habitat constriction for delta smelt and a major reason for its absence in the San Joaquin region during summer.

15: Phytoplankton in the upper San Francisco Estuary: recent biomass trends, their causes and their trophic significance
Author(s): A. D. Jassby
Year: 2008
Journal: San Francisco Estuary and Watershed Science
Volume: 6
Number: 1
Pages: Article 2
URL: http://escholarship.org/uc/item/71h077r1
Relevance to X2 and LSZ: The paper examines the effect of flow on phytoplankton biomass in the context of an empirical model that attempts to separate contemporaneous flow conditions from other, perhaps unidentified, forces behind the long-term trend. Regional phytoplankton biomass trends during 1996–2005 are positive in the Delta and neutral in Suisun Bay. The trend in Delta primary productivity is also positive. Changes in phytoplankton biomass and production during the last decade are therefore unlikely to be the cause of more recent metazoan declines. Freshwater flow variability and its effect on particle residence time are the main source of interannual phytoplankton variability in the Delta, including the upward trend. This conclusion is supported by trend analyses; the concurrence of these time trends at widely-separated stations; empirical models at the annual and monthly time scales; particle residence time estimates; and experience from other estuaries. The reason behind Suisun Bay phytoplankton's low responsiveness to flow variability appears to be *C. amurensis*, which has maintained the phytoplankton community mostly at low levels by vigorous filter-feeding. In the past, flows into Suisun Bay generally diluted the higher phytoplankton concentrations within the bay; now they bring in higher phytoplankton concentrations from upstream. Accordingly, Jassby suggests loading of phytoplankton and phytoplankton-derived detritus accounts for much of the phytoplankton carbon supply to Suisun Bay. In the Delta, *Corbicula fluminea* may be conceivably responsible for a significant part of the observed interannual variability in phytoplankton biomass. Macronutrient supply, on the basis of dissolved nutrient levels, does not seem to be important as a determinant of phytoplankton variability. Water temperature increased significantly during 1996–2005. The temperature increase is significant and, at least partially independent of flow changes, but its net effect on the phytoplankton community is unknown because of differential effects on growth and loss processes.

16: Is the response of estuarine nekton to freshwater flow in the San Francisco Estuary explained by variation in habitat volume?
Author(s): W. J. Kimmerer, E. S. Gross, and M. L. MacWilliams

Year: 2009
Journal: Estuaries and Coasts
Volume: 32
Pages: 375-389
URL: http://www.springerlink.com/content/26pr3h5574605083/fulltext.pdf
Relevance to X2 and LSZ: The key finding in this study is that of eight species, only two (American shad and striped bass) had habitat relationships to X2 that appeared consistent with their relationships of abundance (or survival) to X2. The authors conclude that mechanisms other than variation in physical habitat must underlie responses of abundance to flow for most species. The authors calculated an index of total habitat for each species by combining resource selection functions for salinity and depth with estimates of habitat volume at five different flows using the TRIM3D hydrodynamic model. The resource selection functions for the examined species were consistent for data from different sampling programs with the exception of longfin smelt, which had a peak resource value at salinity near 20 in the Bay Study otter trawl (sampling in deeper water, more seaward) but near 10 or less in the other samples (sampling in shallower water, more landward).

17: Salinity trends, variability, and control in the northern reach of the San Francisco Estuary
Author(s): C. Enright and S. D. Culberson
Year: 2009
Journal: San Francisco Estuary and Watershed Science
Volume: 7
Number: 2
Pages: Article 3
URL: http://escholarship.org/uc/search?entity=jmie_sfews;volume=7;issue=2
Relevance to X2 and LSZ: The key conclusion here is that climate is the primary long-term salinity *variability* driver at the seasonal and annual scale. The water projects influence the trend of the annual and some monthly means in outflow and salinity, but exert far less influence on variability. Notably, both outflow and salinity are generally more variable in the water project era concordant with watershed precipitation. However, the water projects have decoupled long-term trends in annual mean outflow and salinity from long-term trends in climate forcing. Outflow trends downward in opposition to the precipitation trend in the post-project period. The authors also note an apparent reduction in fall outflow from the Delta and salinity variability in the northern reach in the last decade as the water projects have operated more closely to maximum export-inflow ratios.

18: An analysis of pelagic species decline in the upper San Francisco Estuary using multivariate autoregressive modeling (MAR)
Author(s): R. Mac Nally, J. R. Thomson, W. J. Kimmerer, F. Feyrer, K. B. Newman, A. Sih, W. A. Bennett, L. Brown, E. Fleishman, S. D. Culberson, and G. Castillo
Year: 2010
Journal: Ecological Applications
Volume: 20
Number: 5
Pages: 1417-1430
URL: http://online.sfsu.edu/~modelds/Files/References/MacNallyetal2010EcoApps.pdf
Relevance to X2 and LSZ: The authors applied a Bayesian (probabilistic) analysis framework to validate fifty-four relationships representing the state of knowledge of how abiotic habitat factors directly relate to declining fish abundance in the upper San Francisco Estuary and indirectly to these fish populations through the food web. An underlying expert model specified whether particular trophic or covariate effects might be influential. X2 and increased water clarity over the period of

analyses were two factors affecting multiple declining taxa (including fishes and their main zooplankton prey). There was a pervasive relationship of spring X2 with abundances of longfin smelt. There is evidence of potential effects of water exports on delta smelt and threadfin shad. Increases in water exports in both winter and spring were negatively associated with abundance of delta smelt and increases in spring exports with abundance of threadfin shad. The results for delta smelt were consistent with multiple effects of temperature, feeding, exports, and introduced species. The results for striped bass are consistent with effects of feeding and water clarity. Covariates (factors thought to be important for one or more of the response variable) explained 51% variation, suggesting that some aspects of the environment that can be managed are associated with the declining fish species (e.g., X2 and exports). Other potential remedial actions would be difficult or impossible to enact (e.g., total removal of *C. amurensis*).

19: Bayesian change-point analysis of abundance trends for pelagic fishes in the upper San Francisco Estuary
Author(s): J. R. Thomson, W. J. Kimmerer, L. R. Brown, K. B. Newman, R. Mac Nally, W. A. Bennett, F. Feyrer, and E. Fleishman
Year: 2010
Journal: Ecological Applications
Volume: 20
Number: 5
Pages: 1431-1448
Relevance to X2 and LSZ: By using multispecies change point models, the authors find strong evidence for a common change point for all POD species in 2002. Abiotic variables, including water clarity, position of X2, and the volume of freshwater exported from the estuary, explained some variation in species' abundances over the time series, but no selected covariates could explain statistically the post-2000 change points for any species. Species-specific, covariate-conditioned change point models indicated step declines in abundances (i.e., abrupt declines that could not be modeled by the included covariates) of delta smelt and longfin smelt in 2004 and of striped bass and threadfin shad in 2002. In a variable-selection model for delta smelt, water clarity and winter exports both had high probability of inclusion and a negative effect. In the variable-selection model for longfin smelt, water clarity and spring X2 had high probability of inclusion. In the variable-selection model for striped bass, water clarity and the autocorrelation term had high probability of inclusion. No variables had high probability of inclusion in the threadfin shad variable selection model. The authors used a hierarchical Bayesian modeling framework, which allows sampling or measurement error to be separated from actual variation in underlying abundances, while fitting a wide variety of process models.

20: Modeling the effects of future outflow on the abiotic habitat of an imperiled estuarine fish
Author(s): F. Feyrer, K. Newman, M. Nobriga, and T. Sommer
Year: 2011
Journal: Estuaries and Coasts
Volume: 34
Pages: 120-128
Relevance to X2 and LSZ: The authors report a 78% decrease in an annual abiotic habitat index for delta smelt over the study period (1967 – 2004). Using the General Additive Model developed by Feyrer et al. (2007), only specific conductance and Secchi depth accounted for a meaningful reduction of null deviance (i.e., unexplained variability). The final model with specific conductance and Secchi depth accounted for 26% of the deviance. The CALSIM II model was used to simulate future X2 scenarios under seven different development (each assuming a constant level of development) and climate change scenarios, representing a range of drier and wetter possibilities. Modeled future conditions produced smaller values of the delta smelt habitat index relative to the

modeled present day condition, the only exception being in critical years when all values were similar and low. These modeling results suggest further declines in habitat across all water year types. The authors conclude that recovery targets for delta smelt will be difficult to attain if the modeled habitat conditions are realized. A key part of the concern for delta smelt is that the lowest levels of suitable habitat coincide with the habitat being located further upstream in closer proximity to anthropogenic sources of mortality such as water diversions and certain contaminant sources. Locations of X2 downstream of the confluence of the Sacramento and San Joaquin rivers results in a dramatic increase in the habitat index, when the LSZ encompasses the expansive Suisun and Grizzly Bays, a larger area of suitable habitat.

21: Microzooplankton grazing in green water—results from two contrasting estuaries
Author(s): J. York, B. Costas, and G. McManus
Year: 2011
Journal: Estuaries and Coasts
Volume: 34
Pages: 373-385
URL: http://online.sfsu.edu/~modelds/Files/References/YorkEtAl2010EstuariesCoasts.pdf
Relevance to X2 and LSZ: Using the dilution method to measure seasonal variations in microzooplankton grazing on phytoplankton, the authors found many instances of saturated as well as insignificant grazing in San Francisco Bay. They suggest that saturation in some cases may result from high particle loads and that insignificant grazing may result from extreme saturation of the grazing response due to the need to process non-food particles. There was no evidence of nutrient limitation for phytoplankton growth. In a series of two-point dilutions run in spring and summer 2007, the authors found increasing phytoplankton growth rates and microzooplankton grazing rates with increasing salinity. Grazing rates in San Francisco Bay and Long Island Sound were similar to those found in other estuaries.

22: Shifts in zooplankton community structure: implications for food web processes in the upper San Francisco Estuary
Author(s): M. Winder and A. D. Jassby
Year: 2011
Journal: Estuaries and Coasts
Volume: 34
Pages: 675-690
URL: http://www.springerlink.com/content/b30544u2xx0l235u/fulltext.pdf
Relevance to X2 and LSZ: This paper documents major changes in the zooplankton species composition in Suisun Bay and the Delta between 1972 and 2008, largely associated with direct and indirect effects of introductions of non-native bivalve and zooplankton species. Previously dominant copepod species were essentially replaced by newly introduced species over the 37-year study period. Major changes occurred also within the mysid community, with a strong decline in biomass by the end of the 1980s and species composition changes in the early 1990s. In Suisun Bay, the historically abundant calanoid copepods and rotifers have declined significantly, but their biomass has been compensated to some extent by the introduced cyclopoid *Limnoithona tetraspina*. The increasing dominance of *L. tetraspina* in the early 1990s in Suisun Bay coincided with declining trends in the average micro- and mesozooplankton size in this region. The Delta has also experienced long-term declining biomass trends, particularly of cladocerans and rotifers, although calanoid copepods have increased since the early 1990s due to the introduced *Pseudodiaptomus spp*. However, zooplankton biomass in the Delta has remained at a low level since the mid-1980s. Changes in the biomass, size, and possibly chemical composition of the zooplankton community imply major alterations in pelagic food web processes, including a drop in prey quantity and quality for foraging fish and an increase in the importance of the microbial food web for higher trophic

levels.

23: Sudden clearing of estuarine waters upon crossing the threshold from transport to supply regulation of sediment transport as an erodible sediment pool is depleted: San Francisco Bay, 1999
Author(s): D. H. Schoellhamer
Year: 2011
Journal: Estuaries and Coasts
Volume: 34
Pages: 885-899
URL: http://bayplanningcoalition.org/wp-content/uploads/Schoellhamer-2001-sudden-clearing.pdf
Relevance to X2 and LSZ:

The paper presents a quantitative conceptual model of an estuary with an erodible sediment pool and transport or supply regulation of sediment transport. The author offers a hypothesis that the Bay contained an erodible pool of sediment that was depleted in the late 1990s. The hypothesis is supported by an analysis of historical changes in bed sediment volume. The study was motivated by a statistically significant 36% step decrease in SSC in San Francisco Bay from water years 1991–1998 to 1999–2007. This step change in the water year mean SSCs from WY 1998 to 1999 was significant (one-sided rank-sum test $p<0.01$) at all sites except San Mateo Bridge. At the interannual time scale of this study, an erodible sediment pool is the difference between the existing sediment mass and the sediment mass of the estuary at equilibrium (no net deposition or erosion). An erodible sediment pool is depleted when transport-regulated suspension becomes supply-regulated. When regulation of suspended sediment crosses the threshold from transport regulation to supply regulation, suspended mass can rapidly decrease. At the interannual time scale, the erodible sediment pool is larger than at the tidal time scale. Changes in the erodible sediment pool caused by changes in hydrodynamic forcing, specifically decreased tidal prism due to construction fill and levees, are assumed to be negligible. Application of the quantitative conceptual model to San Francisco Bay demonstrates that depletion of an erodible sediment pool in 1999 would cause a sudden decrease in SSC. Supply of hydraulic mining sediment increased bed sediment volume by at least 260 Mm^3 in the late 1800s, almost entirely in Suisun and San Pablo Bay. From the early to mid-1900s, there was a second pulse of sediment about 60% of the hydraulic mining sediment pulse and conceivably caused by urbanization or increased agricultural land use. Without an erodible sediment pool, annual suspended mass would be dependent on river supply and would not suddenly decrease, unless the river supply suddenly decreased. The river supply to San Francisco Bay varies annually and decreased 1.3%/year during the later half of the twentieth century (Hestir et al. submitted). The decreasing watershed sediment supply contributes to decreased SSC but cannot account for the step decrease in SSC. According to the author, changes in the San Francisco Bay ecosystem in the 2000s have been symptomatic of the sudden clearing.

Appendix 3 of Final Report:

WORKSHOP SUMMARY:

Technical Workshop on Estuarine Habitat in the Bay Delta Estuary

Convened by USEPA
Sacramento, CA
March 27, 2012

Prepared by:
Brock B. Bernstein

SUMMARY

Technical Workshop on Estuarine Habitat in the Bay Delta Estuary

Introduction

The Technical Workshop on Estuarine Habitat in the Bay Delta Estuary was initiated by USEPA, with support from the Aquatic Science Center (ASC), to obtain scientific input needed to inform EPA on California's Comprehensive Review of the 2006 Water Quality Control Plan for the Bay Delta Estuary. Gathering a number of recognized experts on the hydrology and ecology of the Bay Delta was an efficient way to hear current knowledge on estuarine habitat, tools for modeling and assessing conditions, and how biological indicators and ecological processes respond to movement of the low salinity zone.

More specifically, the purpose of the workshop was to:

- Increase our collective understanding about the attributes of estuarine habitat, and the tools we have for protecting it
- Characterize the response of biological indicators and ecological processes to changing locations of the low salinity zone (LSZ)
- Generate scientific information that EPA and others can translate into recommendations that support the State's Comprehensive Review of the 2006 Water Quality Control Plan (WQCP) for the Bay Delta Estuary

The following sections describe planning for the workshop and the workshop process itself. The workshop summary condenses the input from participants during the small workgroup sessions and the final plenary session. It captures the breadth of opinions, judgments, and viewpoints expressed without attempting to fact check statements, or reconcile / synthesize disagreements or contradictions. Finally, the facilitator's report provides my personal impressions of the workshop and the degree to which it achieved its stated purposes.

Workshop Planning and Process

Planning

A core planning group (Appendix 1) developed the agenda, process, and working materials for the workshop. The core planning group was composed of staff from EPA Region IX, ASC, and an independent facilitator. The goals of the workshop included increasing EPA understanding of estuarine habitat and the low salinity zone, ecological responses to changing locations of the low salinity zone, and scientific tools we have for learning more about the low salinity zone. Initial rough drafts of the agenda and workshop framework were developed by the planning group and sent to invited participants. The planning group incorporated comments and suggestions from invited participants and presenters that helped focus the four central questions in the workshop agenda.

The planning group provided three background documents to invited participants prior to the workshop in order to provide a common starting point and frame of reference for all workshop participants. These were intended as working materials and not as permanent reports subject to a formal review and revision process.

1. Modeling Estuarine Habitat in the Bay Delta (Appendix 2), summarized concerns about the effects of the LSZ, and its position in the estuary, on fish populations. It presented a brief overview of how X2, the 2 ‰ (parts per thousand) salinity isohaline (as measured in kilometers from the Golden Gate), has been used to help manage key aspects of habitat in the estuary and suggested how newer three-dimensional models might improve this management tool.
2. Review of Scientific Papers and Summary of Key Findings (Appendix 3), summarized the results of 23 selected technical papers on X2, the low salinity zone, and ecological processes in the Bay Delta. The list was constructed through an informal process that included several scientists with a long history of involvement in research in the estuary. This product included a brief synopsis of each paper as well as a list of the major areas of agreement, disagreement, and uncertainty in the existing science on the LSZ and its role in the Bay Delta ecosystem.
3. Notes on Estimating X2 (Appendix 4) were prepared to accompany an excel workbook containing 1930-2011 DAYFLOW and X2 data for use by IEP. The last two pages of these notes contain notes about X2 and outflow values available in CDEC and the now discontinued DWR/IEP HEC-DSS database. A compilation of CDEC outflow (1994-present) and X2 (2007-present) data is available on EPA's website (www.epa.gov/sfbaydelta/activities.html under Delta Water Quality Standards).

Workshop process

The workshop agenda and process (Appendix 5) was designed to provide participants with additional technical information through a set of three presentations that focused on the historical ecology of the Bay Delta and the capabilities of current three-dimensional modeling tools. A series of small group sessions then maximized the opportunity for interaction between participants. Not only did the use of four workgroups increase the amount of parallel processing, but the round-robin structure enabled each small group to review the input of other workgroups. This workshop process helped ensure that the workgroup questions were considered from as many perspectives as possible. Finally, the plenary session at the end of the day allowed participants to express and respond to each other's final thoughts on the four questions, thus providing additional context to the internal workgroup discussions.

As explained in the process description attached to the agenda (Appendix 4) a participant was assigned as the reporter to each question with the role of following the assigned question as it rotated from workgroup to workgroup (see Appendix 5 for participants in each workgroup, workgroup leaders, and reporters). Reporters were thus able to capture how participants' input and perspectives evolved as questions were considered through multiple iterations. In addition, project staff observed the workgroups and collected additional, nearly verbatim notes that provided supplementary raw material for the workshop summary and for USEPA's internal use.

Workshop Summary

The following subsections present a synopsis of the comments related to each of the four workgroup questions as they were addressed by three workgroups in turn. This summary includes the points made in discussion, organized around specific topics related to each question and presented without judgments on their accuracy.

Prior to the workgroup discussions, three presentations in the morning highlighted key technical information intended to give participants a common basis of understanding. The three presentations are available online at http://www.epa.gov/sfbay-delta/activities.html (click on Delta Water Quality Standards) and include:

- Historical Perspectives on the Estuarine Gradient (Robin Grossinger, Aquatic Science Center)
- Modeling Estuarine Processes using SUNTANS (Stephen Monismith, Stanford University)
- Modeling Estuarine Processes using UnTRIM (Michael MacWilliams, Delta Modeling Assoc.)

Question 1: Points of agreement, disagreement, and uncertainty

What are the key points of scientific agreement, disagreement, and uncertainty surrounding estuarine habitat and aquatic life in the Bay Delta Estuary? How could scientists and agencies "manage the uncertainty" while advancing the protection of water quality and estuarine habitat?

Habitat

The low salinity zone (LSZ) is not equivalent to estuarine habitat. Estuarine habitat encompasses the range from 0 to 35 ppt salinity and the LSZ is just one part of the overall gradient. Other gradients and important aspects of habitat in this estuary include:

- Salinity – different species and life stages occur in defined salinity ranges
- Temperature – particularly important in bioenergetics, but also as a lethal limiting factor
- Turbidity – important in assisting feeding and evading predation
- Food supply – has changed in composition and/or abundance at all trophic levels in recent decades
- Predation – some changes have enhanced predator effectiveness
- Connectivity among habitats – spawning habitat must be connected to rearing habitat
- Geometry – depth, area and volume of water, and flow are basic elements of estuarine habitat
- Variability at all times and spatial scales, both longitudinal and horizontal

Limiting any essential element of habitat will limit the quality of the habitat. Of these essential elements, many have changed.

Habitat against the shoreline is important, but there is uncertainty about what is going on at these edges. This should be addressed through additional measurements.

Providing a quantity of habitat, or predicting the quantity with models, is easier than predicting or defining / ensuring the quality of that habitat. There were a range of ideas about what constitutes high quality habitat. However, greater landscape diversity provides more temporal and spatial variability in habitat and this variability creates resiliency because it increases the chance species will find what they need. Connectivity between diverse habitats is also important for resiliency. Habitat has to be at the right scale to be effective.

Low salinity zone (LSZ)

The physical attributes of the LSZ depend on where it is in the estuary and uncertainty regarding the effects of its position can be addressed through measurement. There is more certainty regarding the nature of the longitudinal salinity gradient, but less regarding the horizontal gradient. The LSZ is in the middle of the range of habitats. Some physical properties of the LSZ have changed, e.g., it is getting less turbid, the shallow portions of Suisun and Grizzly Bays are getting shallower (losing sediment), and chlorophyll has gone down. There has been a decrease in the variability of fall X2 but it is not clear to some whether this is important.

The LSZ is very productive relative to other parts of the San Francisco Bay-Delta system. However, productivity is decreasing, though there is disagreement on how/why the decease is occurring, e.g., grazing vs. ammonium vs. both. There is uncertainty about the extent of the importance of ammonium to primary production. If productivity in the LSZ increases, there are large uncertainties about how much of this increase would go to pelagic (fish) and how much too benthic (clams) components of the system. If we do increase productivity, it would be better to do so in the spring.

There are large scale declines over time in the abundance of species, especially pelagic species, but there is not good information, and a wider range of opinion, on the cause(s) / mechanisms leading to these declines. The role of the LSZ in these abundance declines is uncertain. For example, there is a larger risk of entrainment when the LSZ is upstream but disagreement on the importance of this to populations.

We know the importance of salinity for aquatic life and the LSZ is an important measure of estuarine habitat for some species. There is more certainty about the importance of the LSZ and flow for resident pelagic species, but less so for salmon and sturgeon. Variability in the LSZ is essential for resident fish but not so much for salmon and sturgeon. Ocean harvest, hatchery output, predation, and conditions in tributaries are more important for salmon than the LSZ. Some species benefit from more saline conditions (higher than 2ppt) but these are generally species of less concern.

The location where high salinity meets low salinity can provide a lot of useful information about the estuary. But we have focused much effort on the physical aspects of the estuary (e.g., geometry and hydrology) and not so much on ecological processes. This results in a very poor capability to predict biological outcomes, a gap that needs more attention.

Master variable

Discussion of a possible “master variable” highlighted fundamental disagreement. Some think that flow is the master variable, while others believe changes in nutrients are the primary driver. Some think the idea of any master variable or essential attribute is flawed, with declines in abundance related to multiple factors. However, it is hard to find any indicator that is not affected by flow and landscape. Everything is affected by flow, but not the other way around.

The benefits associated with maintaining the LSZ at a specific location are probably achievable at lower flows through landscape or other changes to the estuary.

Uncertainty

The proper response to uncertainty depends on the nature of the uncertainty. If we are uncertain regarding fundamentals such as what is the major stressor, e.g. flow versus changes in nutrients, then there is no clear path forward. However, if we are uncertain regarding the details, then we can measure and adapt.

Uncertainty, based on statistics, has been used as an excuse for no action.

We are uncertain as to the appropriate scale for heterogeneity, but it should be scaled to the available tidal energy.

Other input

A few comments were made that did not engender much reaction or discussion:

- We know something about fish and zooplankton, but we don't know much about microbes, which are involved in important ecological processes
- We don't know as much about wetlands (seasonal and permanent) and the species that use them, as we do about open water
- Historical change has resulted in a shifting baseline, a changing view of what constitutes a good population
- We should design landscapes to accommodate connectivity, scale, and the location of favorable habitat features

Question 2: Need to update management approach

> *What is needed to update and improve the State's current approach of managing estuarine habitat with a springtime salinity standard (FEB-JUN)? What key scientific findings and emerging modeling techniques should be applied?*

The X2 standard: pluses and minuses

When the X2 regulations were originally put into place, it was based primarily on a flow – abundance relationship, not a habitat volume or area relationship, and with less focus on or understanding of the mechanism (s) underlying the relationship. However, there were arguments in the early 1990s that increased productivity was related to positioning X2 near shallow habitat.

There are several species involved; it's unrealistic to expect one metric to represent one ecological function for these different species. X2 provides an index of multiple functions for different fishes. Perhaps the current standard is the right tool, but its implementation is confounded because it was thought of as controlling one variable of importance to all fish, rather than multiple mechanisms that affect different fish differently.

Suggestions for improving the current approach

Extend the salinity standard back a few months into December would help address concerns that longfin smelt eggs are incubating starting in December and we may be missing a benefit by not protecting outflows during that period. This might not need to happen every year but only in the critical years. This would require more basic research to better understand the functional relationship between different life stages and outflow and X2 position.

De-discretize the X2 trigger points (e.g., the Roe island triggers) and make the X2 requirement responsive to the continuous nature of the flow-abundance relationship. The standard would then have no trigger points and a finer temporal scale than the one-month increment. However, the tidal excursion in any given day is so great that it raises questions about what the habitat really is when the standard is applied.

Develop the capability to directly update measurements of bottom salinity in real time.

Consider other indicators of flow, such as something that captures the temporal variability in flow. For example, pulses may be very important regardless of where X2 is positioned.

Link the regulations to underlying mechanisms to the greatest extent possible. This would involve improving the relationship between the X2 management and a more refined description of the mechanisms that are indexed by X2 and their relationship to species biology. For example, a transport mechanism for a particular fish species may produce a different X2 standard than would a food production mechanism. This would involve working species-by-species (for key species) to establish what drives species abundance and what their habitat needs are, which would help in accounting for the expected outcomes of increased flows. Any links between abundance and outflow / X2 can contribute to an aggregated outflow / X2 standard. Any potential X2 recommendation should be clear as to the *uncertainty* associated with it. However, while mechanisms are helpful for refining and optimizing regulation, they are not required. When knowledge of mechanisms is lacking, the empirical relationship between flow or LSZ position and fish population response is more than sufficient to establish a regulation.

Expand the range for adaptive management by crafting more than one set of standards. For example, manage outflow for nutrients in one year and LSZ position (or something else) in another year. There is more storage south of Delta now than there was in 1995, which provides additional flexibility in years that call for reduced exports.

Take a year-round approach (perhaps based on water-year type) so that the consequences of spring outflow recommendations do not create adverse effects in the fall. For example, if abundance is just as good when X2 is at 74 as when it is at 65, then X2 could be set where it costs less water in spring, leaving more water available to support habitat in the fall. This would require a more holistic standard that included a fall X2 standard that acknowledges upstream storage conditions.

Improve the assumptions in the equations that relate X2 to other water quality conditions (e.g., stratification). The assumptions are currently very conservative and better models could potentially allow more goals to be achieved with the same amount of water.

Require an overall cost-benefit analysis of incremental changes in outflow. For example, if the water costs of Roe Island are high, ensure that the policy has achieved an acceptable marginal benefit for that water increment.

Conduct direct measurement of X2 on a more continuous scale, at least for a few years to improve the calibration of the current interpolation algorithm.

Conduct a multi-day intensive workshop to develop the justification that links each species' stressors to particular outflow amounts and LSZ positions.

Include the following question as part of the decision process: "*If you have ___ [limited] water to spend, how would you allocate the water*?" For example, generate as many Chipps Island compliance days as possible.

Think more explicitly about fish downstream, in the pelagic zone, that don't usually receive as much attention, e.g. starry flounder and Pacific herring.

Broaden the definition of LSZ-related habitat. It is not just the volume between two narrow salinity boundaries (e.g. ½ -6 psu, instead, for some species, it should be measured from "where the lower boundary was" (e.g. the volume *up to* 6 psu).

New knowledge that can improve LSZ management

There are scientific discoveries and new modeling techniques that should be applied to managing the LSZ.

New models and tools include:

- Life cycle model
- Turbidity model
- Three-dimensional modeling of habitat
- Bioenergetic models
- Foodweb models
- Sensor arrays
- Otolith microchemical techniques useful for determining natal habitat and conducting retrospective life history analyses

Apply more consistently the improved capacity to build conceptual models and tie these to study plans and quantitative studies.

Develop quantitative models of biological processes, which would allow for more rigorously addressing biological hypotheses.

Better define the behavior of fish habitat (conceived more broadly) in relationship to LSZ position by developing budgets for food plankton, turbidity, and other parameters. Optimizing water flow for production of certain key habitat features requires a better understanding of what needs to be optimized, in terms of habitat features, for each of the different species.

Build on the current capability to develop models predicting when, where and how much phytoplankton growth occurs under different LSZ positioning scenarios by addressing where, when, and how food is being *transported* into the various habitats (e.g., Is it locally produced? Is it advected in?). This is particularly critical for evaluating the food web impacts of wetland/floodplain restoration efforts

Parse out the effect of outflow temporally and spatially to estimate when outflow gets you the most bang for the buck in terms of food production, turbidity, or overlap with critical life history needs of the species.

Historical evidence reveals that some fish species of concern have declined since the X2 relationship was put in place, which suggests that perhaps regulation of X2 for purposes of protecting these species is not warranted, or that the situation is more complex than the original conceptual model envisioned (e.g., X2 may be a surrogate for Sacramento River inflow for longfin smelt). On the other hand, this sequence of events could also be interpreted as a poorly designed and implemented regulation, rather than an incorrect metric or conceptual model. For example, the failure to trigger the Roe Island requirement in many years (achieved by reinterpreting the regulations and manipulating reservoir releases) and the discrete nature of the standard temporally and spatially (e.g., not recognizing the value of each increment of LSZ movement/outflow improvement) may have led to a failure of the regulations to actually implement the conceptual model.

Question 3: Drivers

What are the drivers in the quantity of estuarine habitat during each season of the year? What are the drivers in the quality of estuarine habitat, including the location of the LSZ, during each season of the year? What biological indicators respond to changing locations of the LSZ *between the Carquinez Strait and the western Delta? At the workshop, you'll be asked to fill-in the attached chart of Biological Indicators and Metrics. A sample is attached to stimulate your thinking, and you're encouraged to come to the workshop with ideas for completing this chart.*

Workgroups produced the followings lists of drivers in several categories, along with any key issues or assumptions that influenced or bounded their identification of items listed.

3(a): Drivers in the quantity of estuarine habitat during each season of the year?

Issues/Assumptions

1. Habitat: Focus on LSZ (1-6 ppt) as "habitat". Note, however, that this is based on averaging, both spatially and temporally. There is obviously more variation
2. Quantity: Focus will be on area and areal extent
3. There is much more certainty about the drivers (below); however, processes are likely much more important to organisms and are much less well understood
4. The first three drivers below are generally the most important
5. Spatial gradients vary depending on where the LSZ along the gradient of the estuary
6. The responses to drivers will vary by the type of species. For example, benthic organism responses are different because they occupy more fixed locations
7. Participants struggled with the distinction between quantity and quality; both are obviously important and interrelated
8. Except where indicated, most drivers apply to all seasons

Drivers

1. Landscape, bathymetry, and geography (the effect of landscape has been relatively underappreciated until recently)
   a. Difference of basic geology/geometry in different parts of the delta
   b. Channelization
   c. Levee building, land drainage/reclamation
   d. Levee failure/land inundation
2. Water control structures with highly seasonal operations
   a. Salinity control gates
   b. Flow control gates as at Old River and Delta Cross Channel
3. Flow, Lots of variability in this factor
   a. Rivers, watershed, local tributaries
   b. Need to consider component parts:
      i. Inflow
      ii. Outflow
      iii. Exports
   c. The previous components of flow are affected by multiple factors including:
      i. Flood management
      ii. Flow and temperature requirements
      iii. Water demand
   d. The previous components and factors all vary by season
4. Antecedent conditions affect outcomes
   a. Previous month
   b. Previous seasons
   c. Previous year
   d. Protracted drought
5. Tides

a. Strong effects of the spring-neap cycle
b. Spring-neap differences strongest at the summer and winter solstices
6. Wind
7. Barometric pressure
a. wind
b. Barometric pressure changes can change the location of the LSZ even without wind.

Question 3(b): Drivers in the quality of estuarine habitat during each season of the year?

Issues/Assumptions

1. Quality is assumed to apply to biota
2. Focus is on LSZ

Drivers

1. 1 Physical habitat that can affect organisms directly
   a. Depth
   b. Turbidity
   c. Salinity variation (some differences about the relevance of this factor given the other drivers listed below)
   d. Vertical stratification
   e. Vertical shear
   f. Lateral shear
   g. Temperature
   h. Connectivity
      i. Examples include:
      ii. Channel & off channel areas
      iii. Marsh channels to main channels
      iv. Marsh plains and channels
      v. Channels and adjacent bays
   i. Salinity control structures
   j. Gates
      i. Change salinity distribution
      ii. Change connectivity
      iii. Change transport
2. Physical and biological factors that can affect fish food
   a. All of the above PLUS:
   b. Nutrient loadings
   c. Residence time
   c. Light availability
   d. Food availability
      i. Phytoplankton
         a) Biomass
         b) Composition
      ii. Zooplankton
         a) Biomass
         b) Composition
      iii. Microzooplankton
         a) Biomass
         b) Composition
      iv. Macroinvertebrates

a) Biomass
b) Composition
v. Bioavailable carbon
a) Quantity
b) Composition
3. Structures
a. Anthropogenic, e.g.,
i. Pilings
ii. Mothball fleet
iii. Marinas
iv. Riprap
v. Flow control structures
b. Organic
i. Submerged aquatic vegetation
a) Natives (e.g., *Stichenia*)
b) Invasive (e.g., *Egeria*)
ii. Floating aquatic vegetation (e.g. hyacinth and South American Sponge plant)
iii. Intertidal wetlands
4. Predation / competition
a. populations & distribution
i. striped bass
ii. jellyfish
iii. birds
iv. marine mammals
b. harvest
i. recreational
ii. Commercial (?)
iii. incidental
iv. poaching
v. scientific
c. Competitors
i. Populations and distribution
a) Jellyfish
b) Clams
5. Biological
a. Predation risk
b. Upwelling zones
6. Chemical
a. Contaminants
b. Dissolved oxygen
b. pH

3(c): Biological indicators that respond to changing locations of the LSZ east of the Carquinez Strait?

Issues/Assumptions

1. Focus is on factors that change in response to LSZ position, NOT on all possible things that could be measured
2. Distinction between "things that respond" and "things that are associated"
3. Focus on biota
a. Some participants suggested broadening metrics to other important factors such as turbidity and

temperature
4. Historical record doesn't include full range of conditions needed to fully evaluate this issue
5. The long-term data set is limited by the frequency and timescales of the data
6. Many metrics are supported by actual data. Several metrics are associated with a high degree of uncertainty, but are nonetheless plausible

Metrics

Benthos

1. Corbicula
   a. Density
   b. Biomass
2. Corbula
   a. Density
   b. Biomass

Food

1. Phytoplankton
   a. Distribution (broad scale/fine scale)
   b. Availability (uncertainty about actual degree of response)
   c. Composition (uncertainty about actual degree of response))
   d. Net productivity (uncertainty about actual degree of response))
   e. Patchiness
2. Zooplankton.
   a. Ditto to above
3. Harmful algal bloom occurrence
   a. Distribution
   b. Density

Fish and Macroinvertebrates

1. Delta smelt
   a. Abundance (controversial)
   b. Distribution
   c. Health and condition (uncertainty)
2. Longfin smelt
   a. Abundance
   b. Distribution
   c. Health and condition
3. American shad
   a. Distribution
   b. Abundance
4. Splittail
   a. Distribution
   b. Abundance
5. Starry flounder
   a. Abundance
6. White sturgeon
   a. Distribution (uncertainty)
   b. Abundance (uncertainty)
7. Fish community composition
8. Neomysis
   a. Abundance (uncertainty)
   b. Distribution

9. Crangon
    a. Abundance
    b. Distribution

Other Metrics
1. Predation rates (uncertainty)
2. Wetland plant diversity
3. Scoter and scaup distribution

Question 4: Modeling

> *Given the historical and present-day relationships between the LSZ and the landscape of the Bay Delta, how can models be used to forecast the response of biological indicators to changing precipitation patterns, rising sea levels, and restoration scenarios?*

Components

If modeling focuses on just the LSZ it will miss most of the important factors.

Flow-based questions can benefit from the three-dimensional tools that are available now.

Forecasts of turbidity and temperature will lead to forecasts of primary production. Meteorological data, particularly the fog line, are needed to predict temperature.

It is important to know what is going on at the land water interface because small scale landscape features result in heat exchange. However, sampling only occurs in deeper water accessible by boat.

Predation is an important parameter and small fish avoid clear water because of the higher predation risk. Predation may be involved in the fact that X2 used to be connected to delta smelt but that relationship is now not so clear. It may be hard to predict how shorelines will be affected by sea level rise.

Slower water velocities lead to more cyanobacteria.

The channels in Elkhorn Slough are effective at soaking up nitrogen from the Salinas River and that mechanism may function in the Bay Delta as well.

Integrating biological and physical models

It seems that other estuaries have a three-dimensional primary production model and the Bay Delta does not.

None of the models available today can take vegetation into account. The primary productivity models are crude and thus can’t display temporal and spatial variability. The biological models are less sophisticated than the hydrodynamic models and it has been more difficult to measure and model biological parameters and processes. There has been some unease with linking biological and physical models and it may be worth understanding modeling’s weak links and its limitation in terms of producing clear cut answers / predictions.

Biological processes are important, which raises the question, as one participant expressed it, "Why do we have a Rolls Royce hydrology modeling capability when the biological data and modeling capability are only Pintos?” Dick Dugdale wants to develop a model that would calculate primary production to see if ammonium plays the role hypothesized for it. However, the phytoplankton model hasn't changed since Di Toro's model. Growth rates and grazing data are rudimentary but there is decent chlorophyll model. Dugdale is interested in knowing the concentration of phytoplankton and its export to Suisun Bay and suggests modeling the process. Despite this, other biologists have less interest in modeling in the Bay Delta. This may reflect their background and training, as well as the concentration of funding for modeling in DWR. It may be useful to attract scientists with experience in such modeling in other systems, such as the Great Lakes.

An experiment in the 80's involved slowing down water in the Delta in the spring and produced a large diatom bloom. Similarly, the Sacramento Ship Channel has more delta smelt and lots of chlorophyll and zooplankton. There is enough data and information to begin to pull together the physical and biological models. This would involve connecting physics to nutrients to algae / phytoplankton to zooplankton to delta smelt as a straightforward set of linkages. Any of the existing physical models would lead to the same general results, which could then be layered onto the biology. There are some simple things that could start to provide insight; for example, overlaying several parameters (e.g., temperature, salinity) shows that delta smelt habitat has shrunk.

It is important to begin to integrate physical and biological models but this does not require a new model. Knowledge exchange between biologists and hydrodynamicists, along with attempts to integrate existing data and models, would be a good starting point. Don't be too ambitious and try to model fish immediately; reduce the dimensionality of the problem. Begin with turbidity, temperature, and chlorophyll. Results from physical models may need to be scaled down to fit the level of sophistication or resolution / dimensionality of biological models. In this integration effort, special studies on smaller scales would be useful. For example, the Liberty Island / Cache Slough situation illustrates how there can be high production in the tributaries but none in Cache Slough because of volume, dilution, and mixing factors. Because of the cost of measuring biological parameters, conceptual models and estimates of processes are useful starting points, followed with instrumentation and data collection as understanding improves.

Restoration modeling

Modeling habitat restoration in the Delta is a different challenge and will require new expertise and models. There are not many wetlands in the Delta to work with (in terms of data gathering and modeling) and it is difficult to predict biological outcomes for a habitat that has not been there for 100 years. For example, some managers are thinking that shallow water restoration will produce good food conditions for smelt but research elsewhere suggests this may not be true. And it is not clear that enough is known about sediment supply to predict future Suisun Bay restoration scenarios.

It will be important to work with what's available and manage expectations. Modeling efforts will be more successful if they are focused on a specific location and project.

In addition, restoration involves different stakeholders and perspectives.

Modeling process

Modeling is a sociological process and difficulty in dealing with this aspect is an important impediment to more integrative modeling; this issue has not always been dealt with adequately in the past. Any attempt to integrate biological and physical models will require multidisciplinary teams, better communication, and consistent follow-through. Focused workshops could be an effective way of bringing together the different parties. For such workshops to be effective they must focus on a tightly and clearly focused problem (e.g., what do the three-dimensional flow fields do for food resources for zooplankton at Chipps Island?).

Models' ability to capture secondary indicators and then connect these to primary indicators should be evaluated. For example, can models connect delta smelt abundance to turbidity?

Models have improved over the past several years for many reasons, but partly because of the interaction between data collection and modeling.

Final plenary session

Following the workgroup sessions that focused on individual questions, participants reconvened in a final plenary session (see Agenda, Appendix 5) to hear summaries by the four reporters and then discuss issues highlighted by the earlier workgroup process. The discussion was prompted by questions from the facilitator and centered on the following three areas. As for preceding material, the following is based directly on participants' comments.

Historical ecology

While some participants had been aware of the historical ecology (e.g., information in Robin Grossinger's morning presentation) of the Bay Delta, this information was novel for others. For example, the incursion of salinity in the past was less, and the resistance to tidal incursion greater, than some had understood. Many factors may have contributed to this resistance (e.g., diversity of channels, discontinuity of channels, natural reservoir storage, fewer straight channels) and it would be interesting to see these older historical processes modeled. However, current three-dimensional models have large data requirements. Inputting historical bathymetry into models is relatively simple, but flows / hydrology would be difficult, especially developing a plausible range for base flows.

One way to conduct such modeling would be to begin with simple calculations and explore smaller elements of the system to see how they might work, addressing issues such as the size of the flood basins, the volume of water they could hold, and how tides would propagate in a restricted network of small channels. There are some historical data points, such as the estimated two foot tide in Sacramento in about 1850, that could help establish boundaries for such modeling.

Water and the landscape are important driving factors that determine habitat and quality and the historical perspective is not currently part of the discourse and the historical perspective does not inform everyone's view of the system. In some respects the historical perspective is revolutionary.

Historical information relates to the concept of unimpaired flow, something we know is not natural but that is considered close enough to be useful. The morning's presentation showed that the natural hydrograph and where the water travels are probably enormously different from the concept of unimpaired flow. It is possible that the natural hydrograph is enormously important. This has implications for restoration planning, particularly the issue of how wetlands and islands affect salinity intrusion.

Modeling

The hydrological models are fairly robust but the models that could predict the biological response (e.g., of phytoplankton and fish) are not as well developed or reliable. It is curious that there is not yet a three-dimensional phytoplankton model for the Bay Delta. It would be useful to identify the opportunities for and constraints on improving the biological models and establishing realistic expectations. These biological models would not function like engineering forecast models but it would still be possible to learn a lot about system behavior. Several participants urged that the needed knowledge and tools are available and that such an effort should be undertaken as soon as possible. More integrated models would help inform discussions about ammonium, benthic grazing, and other issues. However, the goal should be to produce models that are only as complex as they need to be and to ensure models are intelligently applied.

An effort to integrate physical and biological models should match levels of sophistication between the different types of models and it may not be wise to immediately attempt three-dimensional modeling of fish responses. Knowledge about higher trophic levels could inform thinking about the integrated models even if they are not explicitly modeled. Phytoplankton would be a good starting point, with the expectation that models would predict biomass fairly well but not do well on fluxes and where plankton are in the water column. One suggestion was to involve Jim Cloern and Dick Dugdale, who are conducting modeling of the South and North Bay, respectively, and have them compare their approaches and results.

In addition to predicting how biological parameters might respond to physical changes, an integrated set of models could help examine a more detailed set of potential costs and benefits of different approaches to X2 management. For example, models could help understand the unintended consequences in the fall of decisions about X2 management in the spring by evaluating the cost-benefit tradeoff of incremental increases in X2 in the spring. Modeling can also be used to help understand the hierarchy of mechanisms that affect ultimate indicators of concern. Increased understanding can then in turn be used to revise monitoring programs to produce data more useful for improving modeling tools. In other words, modeling, interpretation, and data gathering should be viewed as one integrated and mutually supportive set of actions that inform and build on each other.

Habitat

The use of the term “habitat” to refer to the LSZ is problematic and it was suggested that this term, especially as used synonymously with the LSZ, should be removed from participants’ vocabulary. Habitat means different things to different species at different times and places and is an n-dimensional hyperspace. When the term encompasses all dimensions it can become too broad to be useful; when narrowed down to a single species’ particular requirements at one place or time it can be unhelpful for broader management needs. However, the better the understanding of the mechanisms that underlie relationships between species and aspects of the physical environment the better we are able to manage these species. Habitat can be thought of in two useful ways. First, it can refer to aspects of the estuary that are useful, but extremely general, markers (e.g., wetlands). Second, it can be defined as a species’ requirements, only the first few dimensions of which are relevant. One approach would be to use the historic data set to build a description of species-specific responses and mechanisms, with the goal of developing a multispecies management framework. This would be in contrast to the current approach, focused on the LSZ, which some participants described as relevant primarily to delta smelt.

The LSZ is one aspect of habitat; a more useful way to discuss this would be to identify species of concern and identify their requirements. It is also important to keep in mind that management of X2 has downstream effects, including as far as exchange out through the Golden Gate. As understanding and modeling tools improve, it may be possible to conduct experiments that attempt to increase the amount of phytoplankton in the system and to manage its composition.

If contaminants are the primary problem for a fish species, then it would not be productive to define the problem in terms of a lack of sufficient habitat. However, there are regulations and management initiatives that focus on contamination in the Bay Delta. In addition, USEPA’s Advance Notice of Proposed Rule Making, issued in 2011, was intended to focus on both the positive things species need (e.g., habitat) and the negative impacts (e.g., contaminants) that could affect populations. Species need a place to live that is also free from contamination. The Water Boards and other agencies are addressing both types of issues. This particular workshop is focused on the estuarine salinity gradient; other issues (e.g., contaminants) are being dealt with in other venues.

Facilitator's Report

Prepared by Dr. Brock Bernstein

The following are my personal reflections on the structure, process, and outcomes of the Technical Workshop on Estuarine Habitat in the Bay Delta Estuary, held March 27, 2012 in Sacramento, CA.

Overall, I found the workshop to be a productive step toward sharing information, bridging gaps in the understanding and interpretation of key concepts, and developing a shared basis for moving forward on improving the scientific and technical tools for managing key aspects of the Bay Delta's ecosystems.

Workshop planning

The conference calls and email exchanges prior to the workshop were adequate for organizing the workshop and developing the agenda and other materials. Team members' roles were well defined and timelines and interim deliverables were clearly identified and tracked by the USEPA project team. The planning and logistics were extremely well managed and I was impressed at the USEPA team's openness to input, even as the workshop agenda and materials were being finalized. For example, the presentation content and draft workshop questions were revised a few days prior to the workshop based on input from the presenters and other interested parties, in order to better accomplish the workshop's goals.

Workshop structure and process

The morning agenda included three presentations, one on the historical ecology of the Bay Delta and two on advances in tools for modeling hydrology in three dimensions. These presentations provided important background for consideration of the workshop questions and the three presenters were valuable additions to the workgroups. Overall, the workshop participants included an appropriate mix of perspectives and scientific experience, as indicated by the range of opinion expressed in the small and large group discussions.

Participants engaged readily in the workgroup process, which involved rotating the workshop questions through a succession of workgroups. After brief explanation, this worked smoothly and the reporters provided detailed notes that provided much of the raw material for the workshop summary. USEPA staff also sat in on the workgroups, as non-participating observers, and took supplemental notes. Other observers from the public were permitted to view the morning presentations and the workgroup discussions, but were asked to remain silent. The one-day format with only brief breaks was a strain for participants and several noted their fatigue by the end of the day. Nevertheless, the participants all engaged actively in the plenary session at the end of the day and several stated afterward that they were pleased and encouraged by the workshop's outcome. Future workshops of this type should consider a longer schedule with additional breaks.

Based on communications before the workshop, and the past history of ongoing disagreement between some of the participants, I was encouraged by several indicators of a healthy working relationship, including:

- Willingness to share concerns openly with the facilitator before the workshop
- Willingness to suspend judgment where needed and participate in the workshop
- Careful listening and respectful discussion
- Ability to disagree without being disagreeable
- Willingness to acknowledge shifts in their own and others' positions on key issues
- Ability to combine different points of view into more integrated perspectives

Workshop outcomes

The workshop resulted in four outcomes that furnish a basis for further technical work on the issues addressed and for collaboration among the participants and the entities they are associated with.

Technical input

The workshop succeeded in producing substantial technical input addressing the workshop questions. While USEPA has not completed its review and synthesis of the workshop notes and summary, I believe that the presentations and discussion will enable USEPA to fulfill the three specific purposes of the workshop.

Improved clarity on key issues

My interactions with USEPA staff and workshop participants prior to the workshop highlighted important perceived differences of opinion about the meaning of terms such as "habitat" and "low salinity zone" and how these should be used in developing technical tools and policies for managing the Bay Delta.

Discussion during both the workgroup sessions and the final plenary session demonstrated broad agreement that the concept of habitat includes a number of physical and biological dimensions and that the LSZ captures only some of these. These dimensions will differ across species, life stages, and time. Habitat and LSZ are thus not synonymous, although salinity is certainly an important aspect of habitat. A more thorough understanding of habitat may therefore require species-by-species studies of the requirements and the mechanisms that affect these.

A corollary of a broader definition of habitat is that the LSZ is not the only cause of change in the estuarine ecosystem. In particular, historical ecology studies document the radical changes that have occurred in the Bay Delta's morphology and hydrology. This has the potential to affect assumptions about how closely existing processes can mimic natural condition (e.g., unimpaired flows), the design of studies to improve understanding of estuary function (e.g., resistance to salinity intrusion, and expectations of restoration potential.

Recommendations for new studies

Participants identified and generally agreed on the value of two types of new studies which were prompted in large part by information in three morning presentations. The first was efforts to integrate biological and physical models of estuarine processes, beginning with phytoplankton. The second was attempts to model the historical hydrology of the estuary. Both are described more completely in the section on Question 4: Modeling, above.

Improved environment for collaborative work

Several participants believed that the workshop outcomes, especially the general agreement on definition of key issues and recommendations for new modeling studies, were significant and opened the door to more productive discussion and collaborative efforts in the future. One such effort I heard suggested was the use of a joint fact finding process to engage parties with different perspectives on the management of the Bay Delta in a structured effort to identify a common basis of factual information and rigorously identify and attempt to resolve sources of disagreement.

Appendix 1: Workshop Planning Group

Members of the workshop planning group included:

• Bruce Herbold	US Environmental Protection Agency
• Tim Vendlinski	US Environmental Protection Agency
• Erin Foresman	US Environmental Protection Agency
• Thomas Jabusch	Aquatic Science Center
• Brock Bernstein	Consultant

Appendix 2: Modeling Estuarine Habitat in the Bay Delta

Modeling Estuarine Habitat in the Bay Delta

Unifying One and Three Dimensional Approaches to Modeling X2 and the Low Salinity Zone[190]

Estuarine Habitat and the Low Salinity Zone

Estuaries are coastal areas where rivers mix with seawater in semi-enclosed basins. The San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay Delta) is the largest estuary on the west coasts of North and South America, draining 40% of California's land area and encompassing the 478-square mile Bay, and the 1,153-square mile Delta[191]. Hydrodynamic processes ensue when light freshwater meets heavy seawater, and these processes both concentrate suspended solids and aquatic organisms, and comprise the *estuarine habitat* that supports multiple life stages for a diversity of fishes.

The location and extent of estuarine habitat fluctuates in response to river flows, ocean tides, weather, and geographic features (e.g., levees, the depth and breadth of stream channels, connectivity to adjacent wetlands). The *low salinity zone* (LSZ) occurs at the inland edge of estuarine habitat where average daily salinities range from 1 to 6 practical salinity units (psu)[192]. The turbidity of the LSZ results from the concentration of suspended solids, phytoplankton, and zooplankton, and these turbid conditions both shelter and provide food for young fish[193].

Anthropogenic Changes and Current Conditions in the Delta and Suisun Bay

Beginning in the 1850s, over 300,000 acres of tidal marshes in the Delta were diked, drained, and converted to agriculture[194]. Thus, the complex, shallow, and dendritic marshlands were replaced by simplified, deep, and barren channels (Figure 1). This hydrogeomorphic modification fragmented aquatic and terrestrial habitats, and decreased the quality and quantity of available estuarine habitat.

190 Drafted by Herbold and Vendlinski for the Technical Workshop on Estuarine Habitat (27 March 2012).

191 The State of the Estuary: A Report on Conditions and Problems in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (SFEP, 1992).

192 The UNESCO Practical Salinity Scale of 1978 (PSS78) is used to describe the concentration of dissolved salts in water and defines salinity in terms of a conductivity ratio. Salinity was formerly expressed in terms of parts per thousand (ppt) or by weight (parts per thousand or 0/00). That is, a salinity of 35 ppt meant 35 pounds of salt per 1,000 pounds of seawater. The salinity of freshwater is 0 psu and the salinity of the open ocean ranges from 32 to 37 psu. http://science.nasa.gov/glossary/practical-salinity-unit/

193 Kimmerer, W. J., J. R. Burau, and W. A. Bennett. (1998). "Tidally oriented vertical migration and position maintenance of zooplankton in a temperate estuary." Limnology and Oceanography. 43(7): 1697-1709.

194 Delta Ecosystem White Paper (October 2010), pages 4-5.

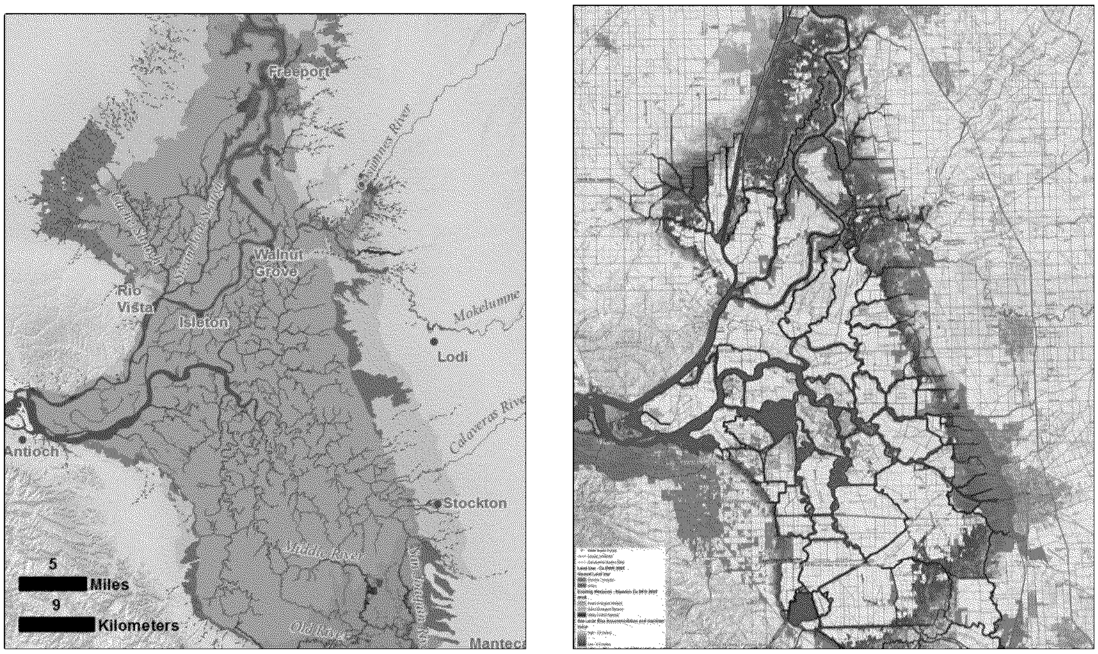


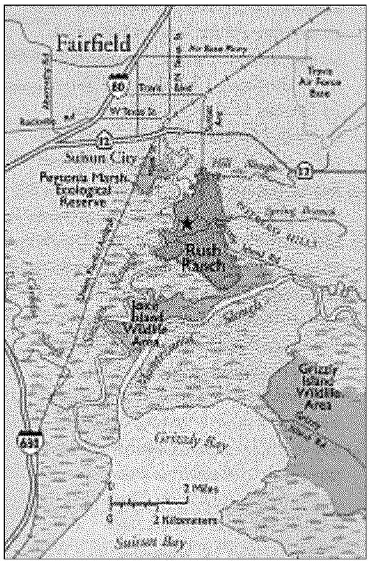
Figure 1: The Delta before and after diking and draining. The draft map of the Delta in the early 1880s on the left is courtesy of Grossinger and Whipple, SFEI (2012). The map of the post-modification, modern day Delta on the right was drawn from USBR-ESRI[195].

Since the year 2000, the position of the LSZ has been frequently fixed in the western Delta throughout the summer and fall until the first storms arrive. As a result, estuarine habitat is located in deep river channels for a large fraction of the year and exposed to a variety of stressors[196]. Fishes that follow the LSZ into this area face an increased risk of predation and entrainment resulting from a lack of cover and foraging habitat caused by the simplification of geographic features, and by the design and operation of water supply infrastructure. By contrast, when the LSZ occupies Suisun Bay, the estuarine habitat spreads out across the expansive shallows of Grizzly and Honker bays and into the large adjacent tidal marsh (Figure 2).

195 USBR-ESRI: The California Delta—Ecosystem Restoration Targets and Levees at Risk.
In comparing their maps of the early 1880s Delta with the early 2000s Delta (the latter not pictured in this paper), Grossinger and Whipple found the maps revealed a reduction in historical tidal channel complexity with the damming of smaller waterways, channel widening, meander cuts, and straight connecting canals. The mapping done by USBR-ESRI led them to conclude that subsidence and anticipated sea level rise have limited restoration opportunities for aquatic and terrestrial habitats. This would apparently exclude the western Delta from consideration as a restoration target, however, USGS has demonstrated that subsided islands in the western Delta are restorable, and the subsidence reversible, through carbon farming with tule-based wetlands.

196 For the purposes of this paper, the "western Delta" refers to the area around Sherman Island at the confluence of the Sacramento and San Joaquin rivers, river km 81 to 90.

While the form and function of the marsh have been greatly altered, the remnant wetlands still bear a resemblance to the habitat that once characterized both the Suisun Marsh and the western Delta. Most of the wetland acres within Suisun Marsh are managed for waterfowl, but there remain many dendritic sloughs lined with extensive fringing tidal wetlands. Suisun Marsh continues to shelter a number of aquatic species that are rarely found elsewhere in abundance.



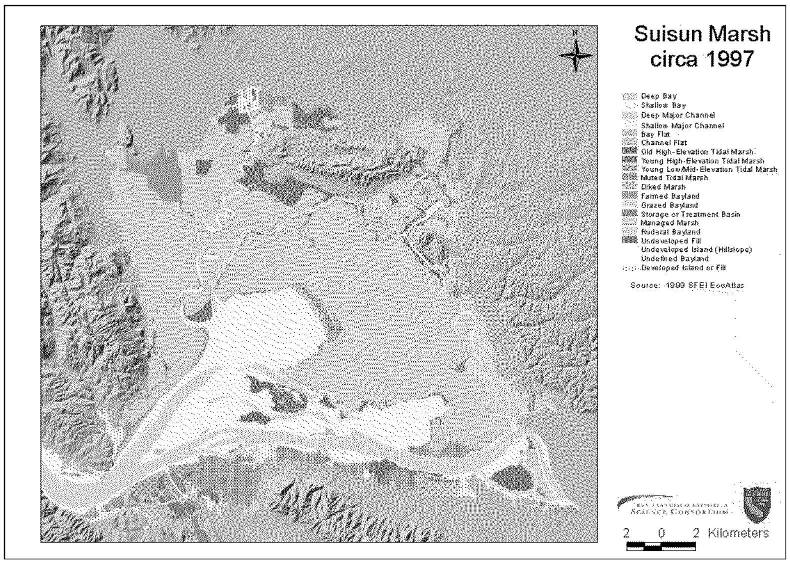


Figure 2: Suisun Bay and Marsh comprise the only area upstream of San Pablo Bay where shallow embayments are contiguous with significant, remnant patches of tidal marsh. Here, optimal estuarine habitat can be created by using Delta outflows to co-locate the LSZ with these geographic features. Map on left from Bay Nature (2001); map on right from CDFG's Suisun Marsh Atlas.

A number of species that often reside in the LSZ (e.g., delta smelt, longfin smelt, young striped bass), and a number of species that move in concert with the LSZ but are associated with higher salinities downstream (e.g., Pacific herring, starry flounder, and native shrimp species) show a greater abundance and survival when the LSZ shifts downstream from the western Delta and toward Suisun Bay. With the exception of delta smelt, the aforementioned species show a relatively straightforward, positive relationship between the westward locations of the springtime LSZ, and their greater survival as young fishes, or abundance as adults197.

197 Kimmerer, W. J. 2002. Effects of freshwater flow on abundance of estuarine organisms: physical effects or trophic linkages? Marine Ecology Progress Series

A Brief History of X2

An *isohaline* is a line that connects all points of equal salinity in an estuary. Isohalines generally move in parallel with each other and in response to ocean tides, freshwater inflows, and, to some extent, atmospheric pressure. The abundance and survival of most of the aforementioned Bay Delta species are correlated with the location of the 2 ‰ (parts per thousand) salinity isohaline -- as measured in kilometers from the Golden Gate (Figure 3). In the early 1990s, scientists designated this parameter as *X2*198, and since then, scientists have sought to understand the mechanisms behind the relationships of X2 with aquatic resources, and the changes in those relationships through time. Despite its statistical association with a variety of aquatic resources, the one-dimensional nature of the X2 parameter does not reveal the ecological processes that underlie those associations.

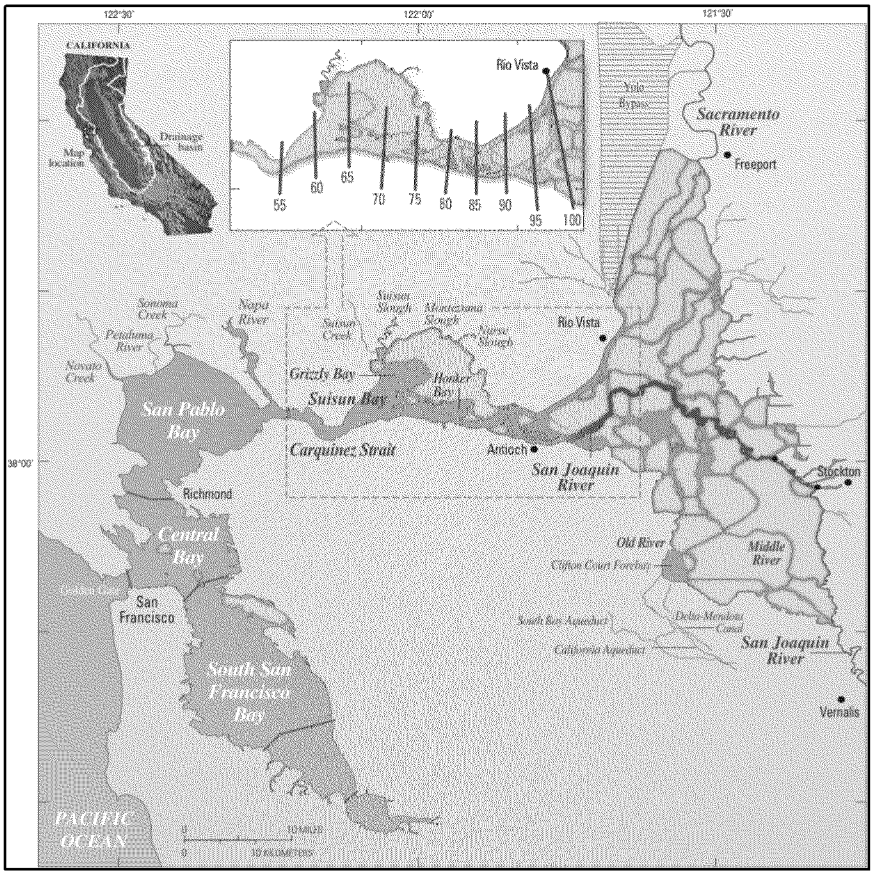


Figure 3. Isohaline positions (X2) measured at nominal distances (in kilometers) from the Golden Gate Bridge along the axis of the estuary. New ap by DeLio (2011) adapted from Jassby et al. (1995).

198 Jassby et al. 1995 Isohaline Position as a Habitat Indicator for Estuarine Populations. Ecological Applications 5: 272-289.

Kimmerer and Monismith developed *the X2 model* to predict the location of X2 based on the preceding location of the isohaline and the present value of delta outflow199, while Denton developed *the G model* to predict salinity at a particular location (intakes for drinking water) based on previous salinity conditions at that location and present delta outflow200. Today, X2 positions are interpolated from measurements of salinity at four locations in the Bay Delta and reported daily.

The Translation of X2 into Water Quality Standards

In 1995, the State Water Resources Control Board (State Board) adopted X2 as a water quality standard to help restore the relationship between springtime precipitation and the geographic location and extent of estuarine habitat. The regulatory requirements for this springtime (February through June) standard are indexed to monthly flows into reservoirs on the eight largest rivers draining into the Bay Delta201. This requires water managers to position X2 further downstream in wet months than in dry months either by increasing reservoir releases or, more commonly, decreasing exports from the Delta. Compliance is achieved by positioning X2 downstream of one of three locations: Roe Island (65 km), Chipps Island (74 km), or the confluence of the Sacramento and San Joaquin rivers (81 km). The State Board did not set standards for managing the location of X2 during other times of the year.

Following the State Board's implementation of the X2 standard under the 1995 Water Quality Control Plan, more characteristic springtime flows prevailed in the Delta, and migratory and resident fishes responded with modest yet significant increases in abundance. By 1999, increases in the population of delta smelt nearly achieved the criteria for delisting set forth in the federal recovery plan for native fishes in the Delta202. Moreover, populations were rebounding for both threadfin shad and longfin smelt, and populations of adult striped bass returned to levels not seen since the 1970s. However, beginning in the early 2000s, populations of delta smelt and other pelagic species experienced unexpected and dramatic declines, and this phenomenon became known as the *pelagic organism decline* (POD)203 .

199 Wim Kimmerer (SFSU) and Stephen Monismith (Stanford University) developed the "X2 Model." Historical X2 is included in the DAYFLOW dataset, and calculated using this model.
200 The "G Model" developed by Richard Denton of Contra Costa Water District.
201 Eight largest rivers draining into the Bay Delta and their corresponding Reservoirs:
American River (Folsom Lake), Feather River (Lake Oroville), Merced River (Lake McClure),
Sacramento River (Lake Shasta), San Joaquin River (Millerton Lake), Stanislaus River (New Melones Reservoir), Tuolumne River (Don Pedro Reservoir), and Yuba River (Engelbright Lake).
202 FWS: Recovery Plan for the Sacramento/San Joaquin Delta Native Fishes (1996).
203 Baxter, R., R. Breuer, L. Brown, M. Chotkowski, F. Feyrer, M. Gingras, B. Herbold, A. Mueller-Solger, M. Nobriga, T. Sommer, and K. Souza. 2008. Pelagic organism decline progress report: 2007 synthesis of results. Interagency Ecological Program for the San Francisco Estuary, Technical Report 227.

Modeling X2 and the Low Salinity Zone with 3D models

The LSZ is a three dimensional (3D) volume of estuarine habitat that changes its shape depending on its location in the Bay Delta. New models allow for the 3D characterization of the LSZ in terms of its average depth, width, and river kilometer, and can depict the dispersion of the LSZ over short time steps.

These models include the UnTRIM San Francisco Bay-Delta model (UnTRIM) that the Delta Modeling Associates adapted for use in the Bay Delta. Other models include the SUNTANS model developed by researchers at Stanford and U.C. Berkeley, and a public domain model being developed by DWR[204]. All of these models can, or have the potential to, characterize the hydrodynamics of the Bay Delta in a fine geographical scale and with small time steps that more closely mimic real world conditions than the aforementioned X2 and G models.

The following is not intended to be an endorsement of the UnTRIM model per se, but rather an exploration of the potential advantages of using a 3D approach toward characterizing the LSZ of the Bay Delta. EPA became aware of the UnTRIM model during the regulatory review of the proposed Sacramento Deep Water Ship Channel project proposed by the Corps of Engineers and the Port of West Sacramento.

The UnTRIM model was calibrated using data collected in the Bay Delta about water levels, flow, velocity, and salinity. The model provides a 3D hydrodynamic characterization of conditions from the Pacific Ocean eastward through the entire Sacramento-San Joaquin Delta. Predicted water levels were compared to observed water levels at monitoring stations administered by DWR and NOAA in San Francisco Bay, and those administered by DWR and USGS in the Delta. Large grid cells were used to characterize the Pacific Ocean, and these cells gradually transition to finer grid resolution for the small channels of the Delta (Figure 4). This approach allows for detailed analysis of local hydrodynamics, while still incorporating the overall hydrodynamics of the larger estuary in a single model.

204 Stanford Unstructured Nonhydrostatic Terrain-following Adaptive Navier-Stokes Simulator (SUNTANS)

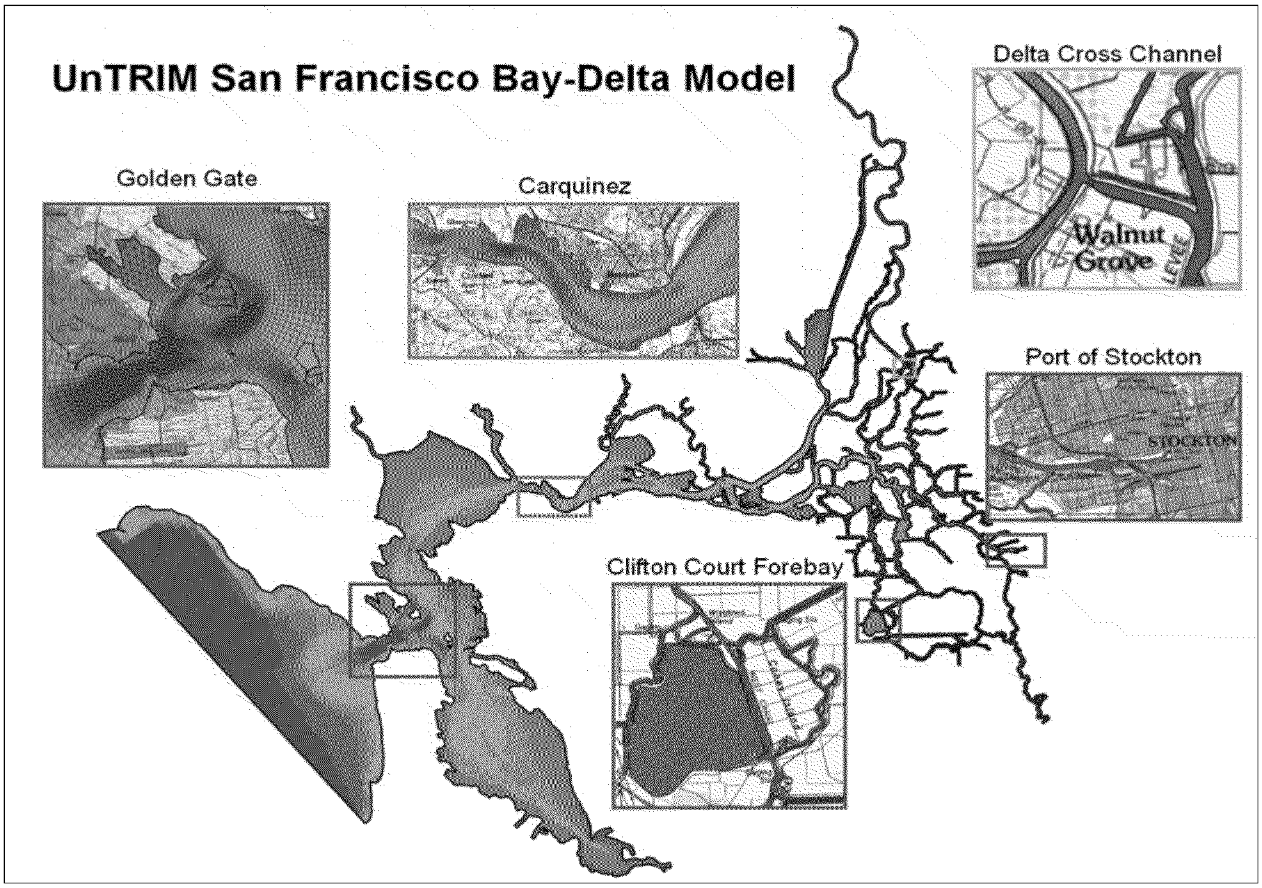


Figure 4. The domain and samples of the computational grid for the UnTRIM model.

Characterizing the LSZ in relation to X2 using the UnTRIM Model

In the figures below, the volumetric UnTRIM model was used to characterize: (i) the areal extent of estuarine habitat (in hectares) corresponding to the regulatory compliance points established for X2 under the 1995 Water Quality Control Plan; and (ii) the percentage of time per day the LSZ resides in a given location of the Bay Delta205. Presenting the data in this way unifies the 1D approach employed by the State Board since 1995 to manage the location of X2, and the 3D approach (depth, width, and river kilometer) now available to characterize the position and volume of the LSZ.

205 The ability of the UnTRIM model to account for time means it can be used to model a 4th dimension of estuarine hydrodynamics.

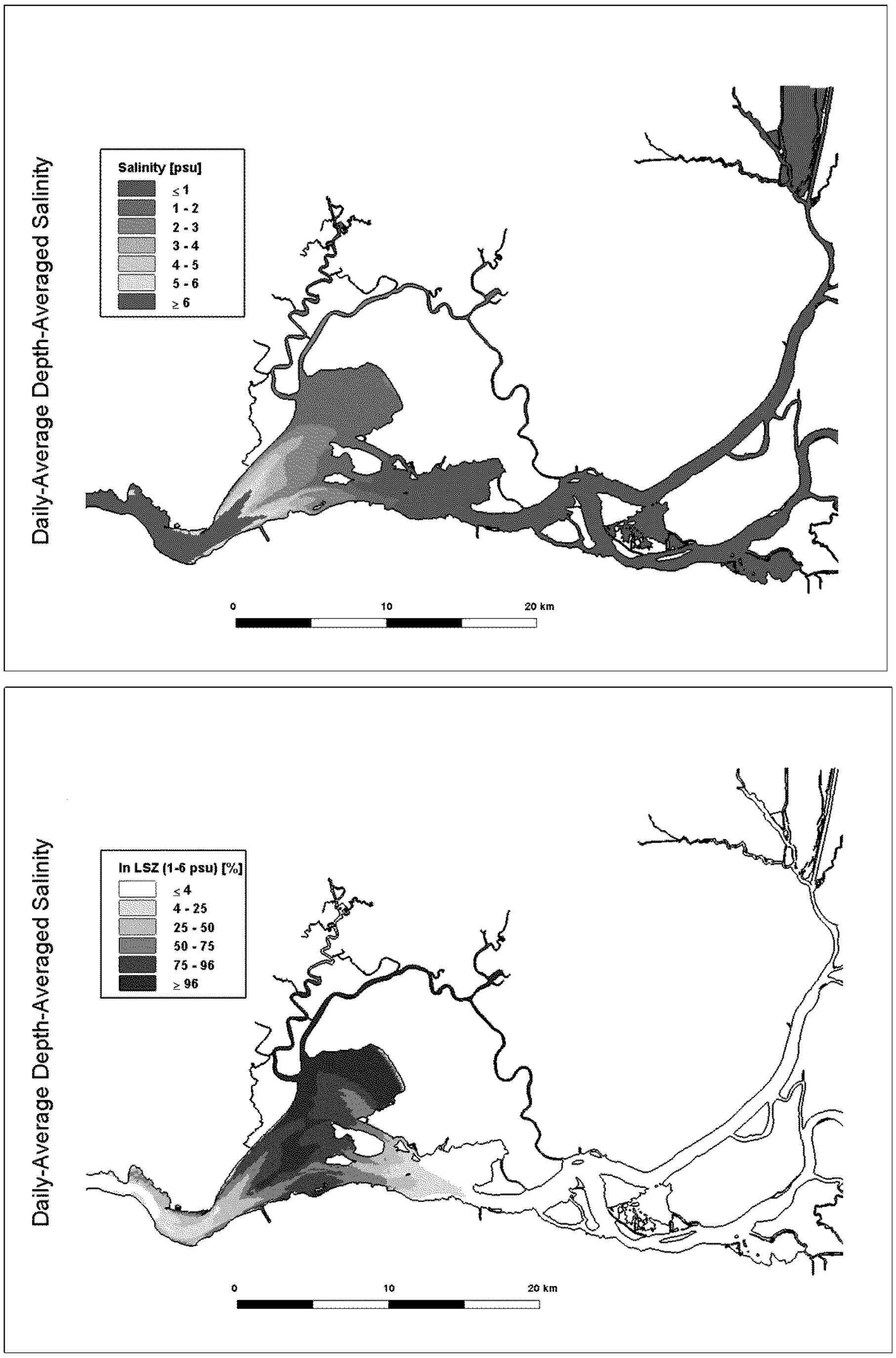


Figure 5a & 5b. X2 = 65 km (downstream of Roe Island). The upper figure shows parts of the LSZ in shades of blue from 1-6 psu stretching across 7,704 hectares and the broadest regions of Suisun Bay adjacent to Suisun Marsh. The lower figure shows the percentage of day that the LSZ occupies different areas of the Suisun Bay and Marsh.

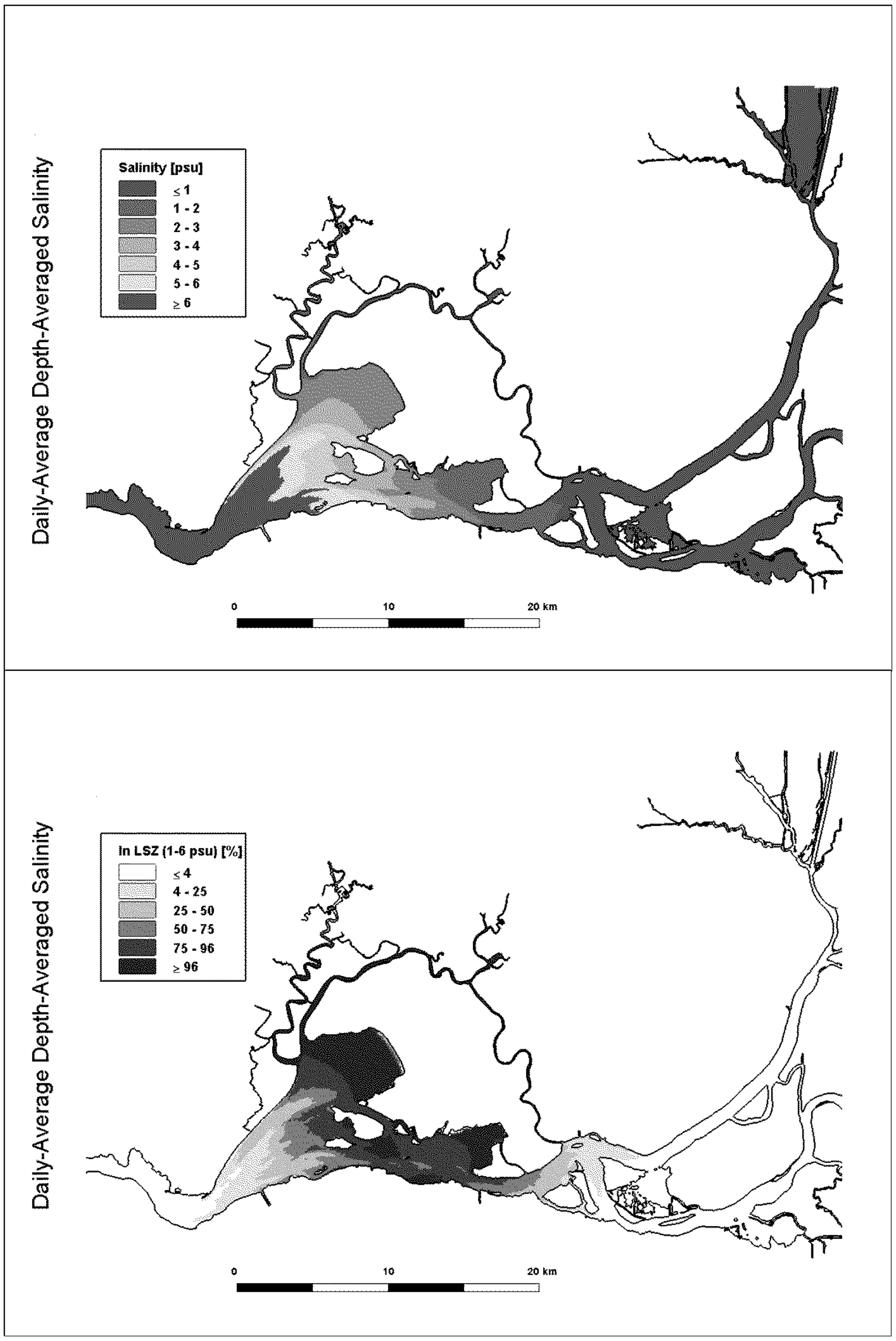
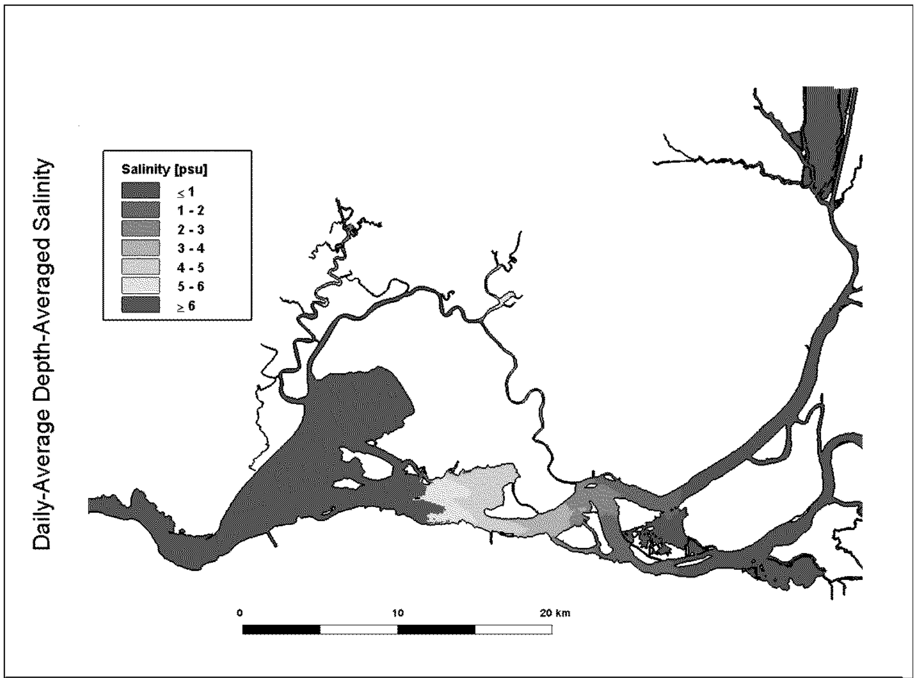


Figure 6a & 6b. X2 = 74 km (at Chipps Island). The upper figure shows the LSZ covering 9,140 hectares. While the total areal extent of estuarine habitat is greater than in Figure 5a, the benefits derived from this greater expanse of the LSZ might be offset by the occurrence of higher salinities across Grizzly Bay and the squeezing of lower salinities into Honker Bay. The lower figure shows the percentage of day that the LSZ occupies different areas.



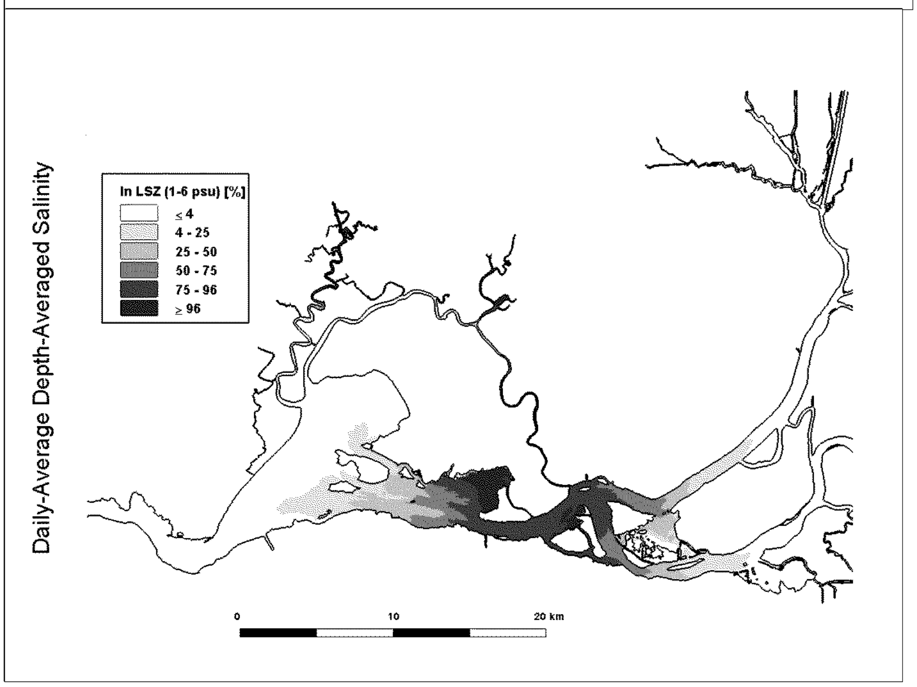


Figure 7a & 7b. X2 = 81 km (at the confluence of the Sacramento and San Joaquin rivers). The upper figure shows the LSZ being compressed into 4,914 hectares within the relatively deep channels of the western Delta. The lower figure shows percentage of day that the LSZ occupies different areas.

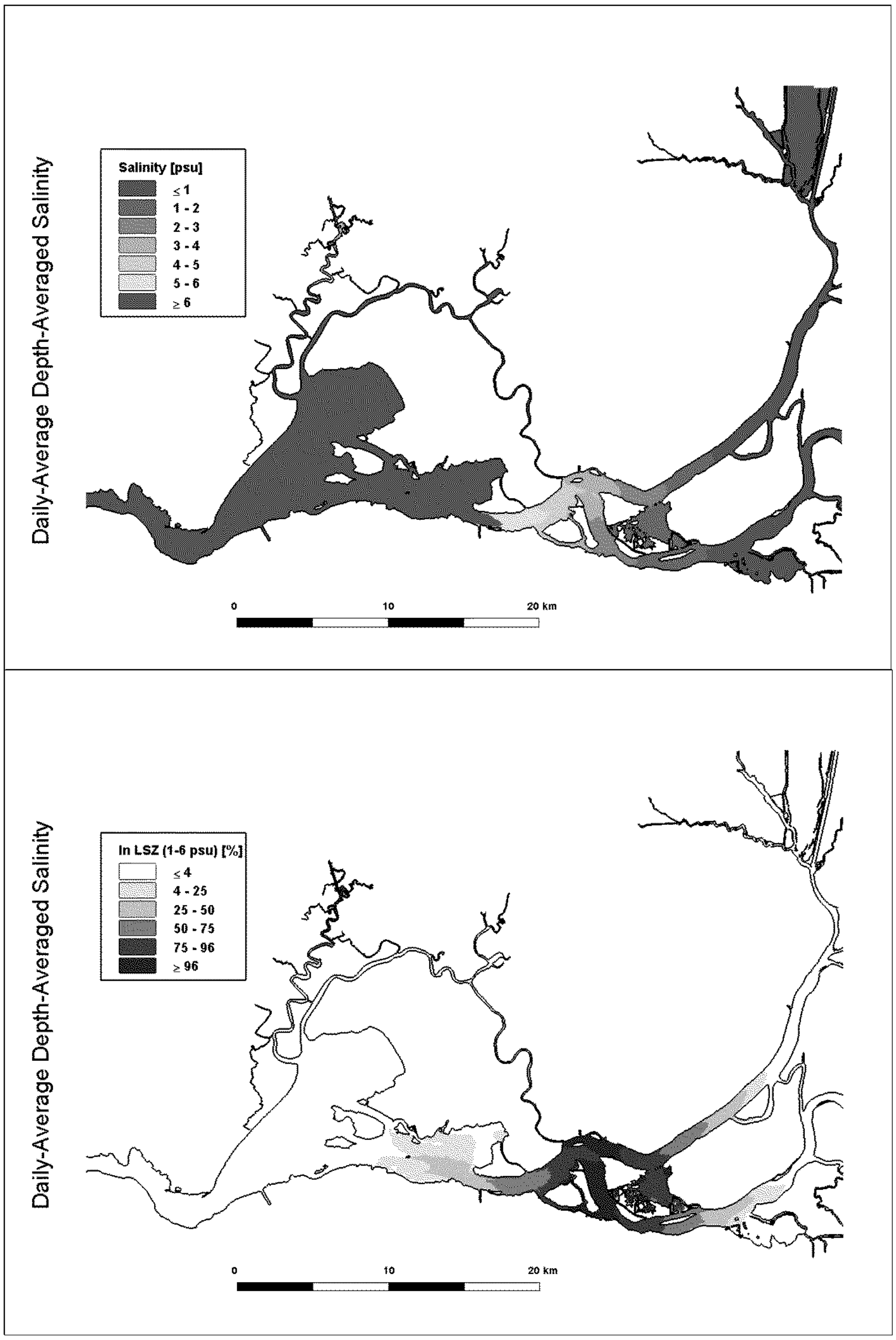


Figure 8a & 8b. X2 = 85 km. The upper figure shows the LSZ being positioned mostly between Antioch and Pittsburg where the areal extent of estuarine habitat drops to 4,262 hectares, and important connections to Suisun Bay and Marsh have nearly been lost. The lower figure shows the percentage of day that the LSZ occupies different areas.

UnTRIM depictions of Depth, Area, and Volume of the LSZ in relation to X2

The diverse geometry of the upper San Francisco Estuary produces different physical characteristics of the LSZ at different locations. The predictability of the relationship between X2 and the physical characteristics of the LSZ is markedly different upstream and downstream of Carquinez Strait.

The area of the LSZ modeled by UnTRIM shows a strong relationship with X2, due to the distribution of shallow habitats along the axis of the estuary. However, this relationship is much more consistent east of Carquinez Strait (X2 > 50) than westward (Figure 9). The relationship of average LSZ <u>depth</u> with X2 is almost perfectly inverse to that of the LSZ <u>area</u> (Figure 10).

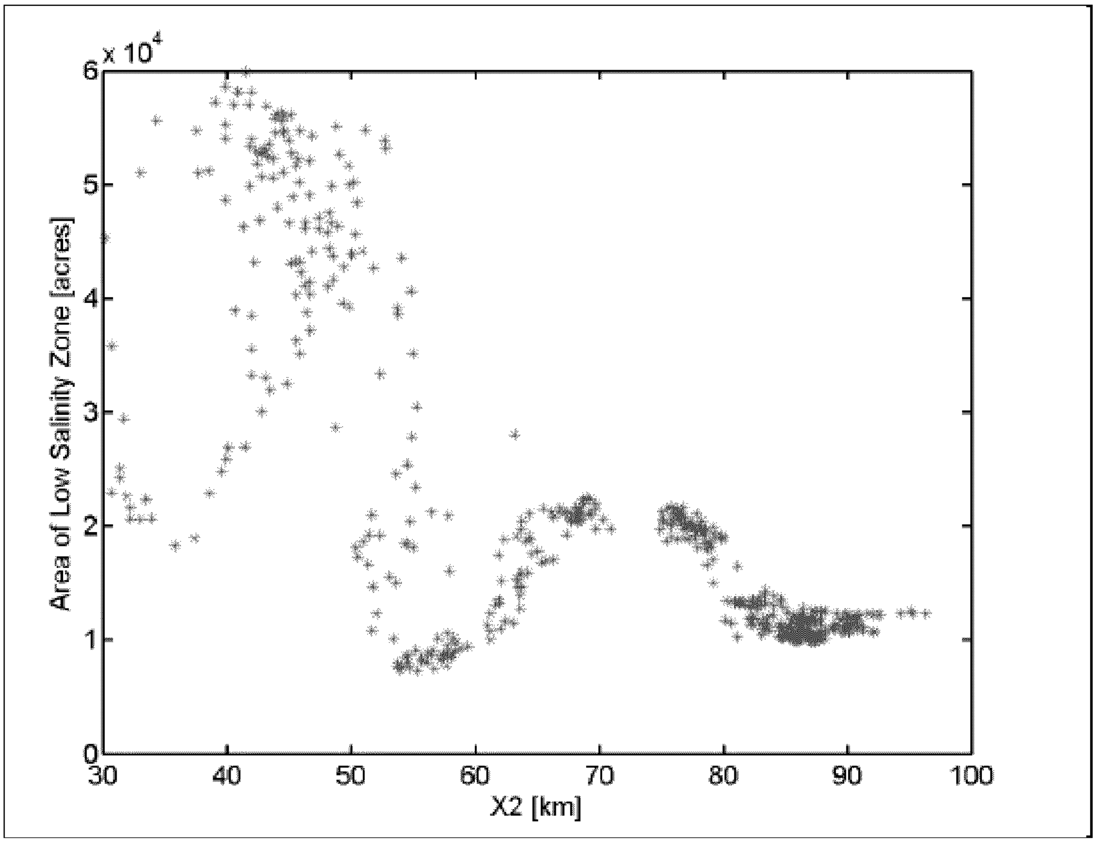


Figure 9. Average acreage of the Low Salinity Zone as a function of X2 using 549 days of data spanning 1 April 1994 to 1 October 1995.

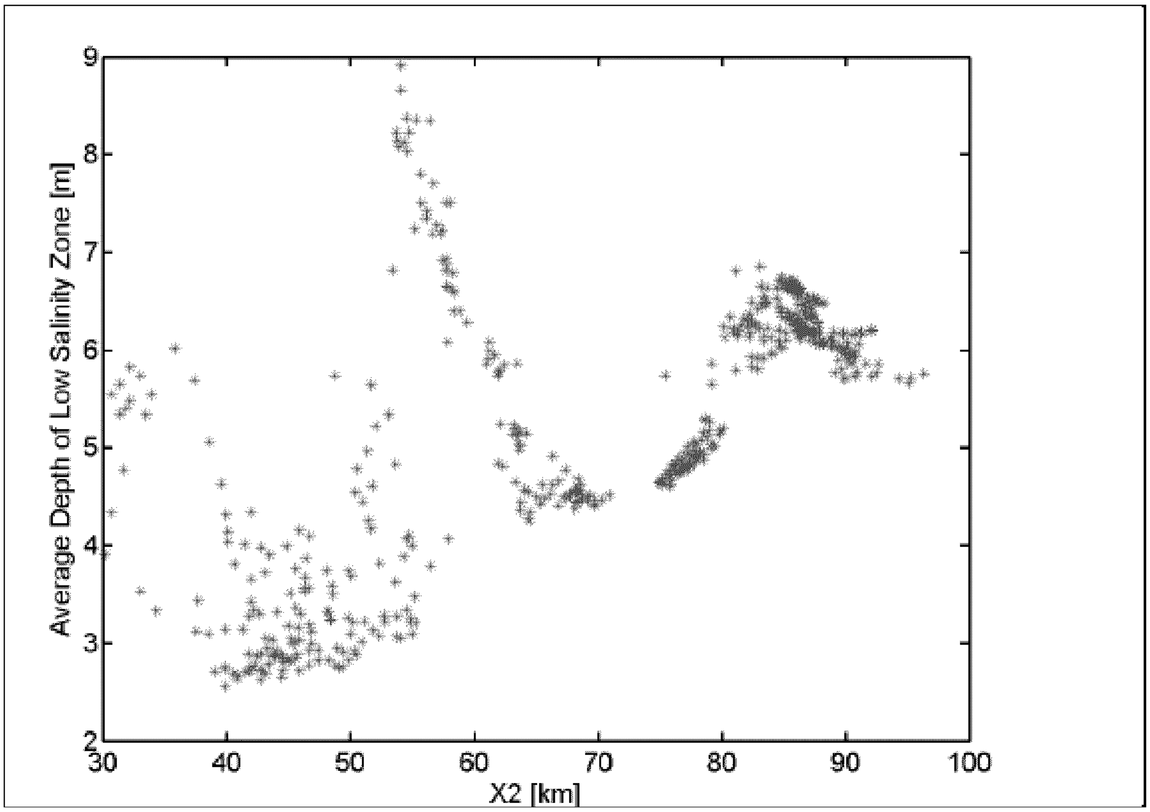
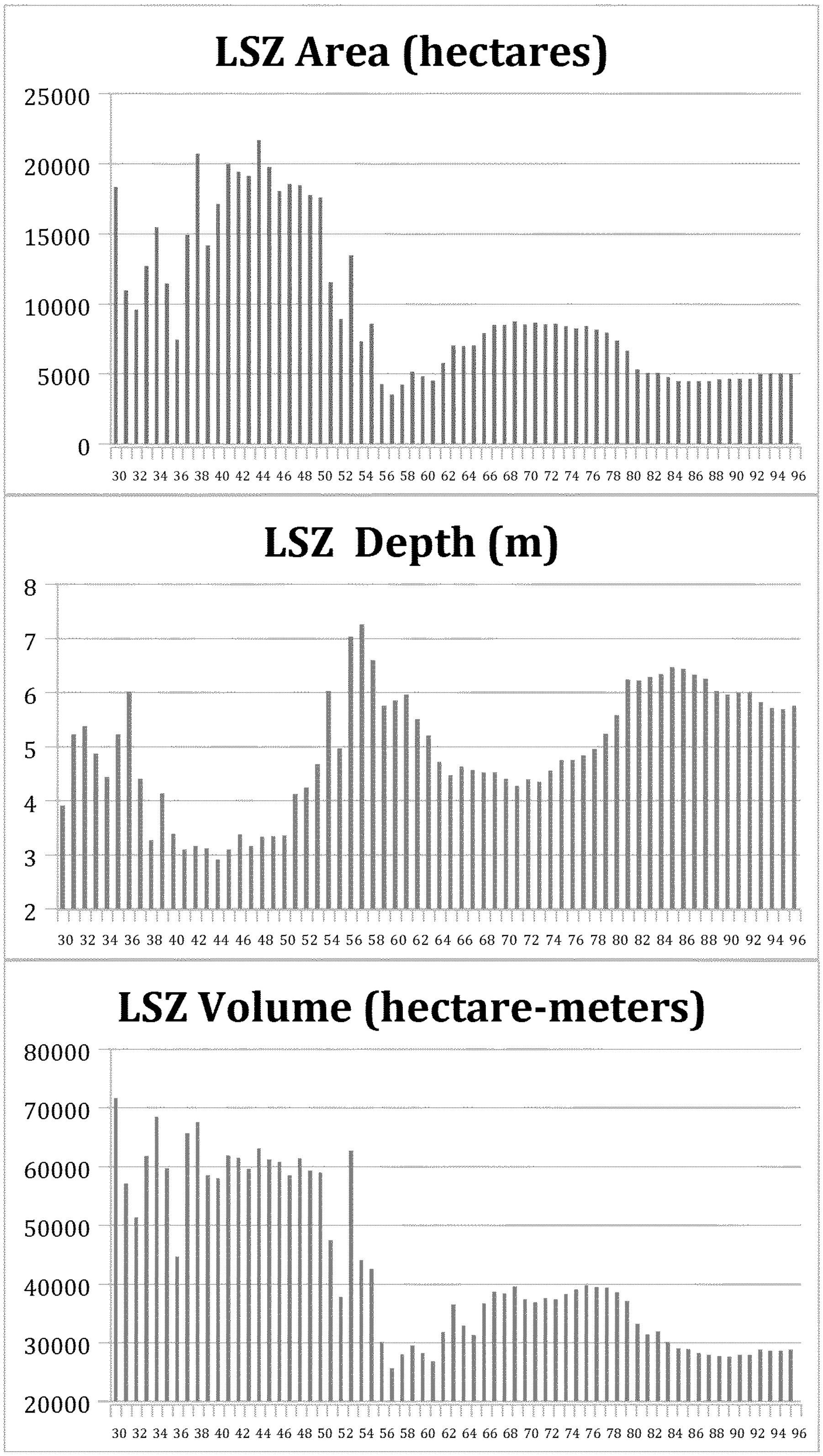


Figure 10. Average depth of the Low Salinity Zone as a function of X2 using 549 days of data spanning 1 April 1994 to 1 October 1995.

The volume of the LSZ shows the least relationship with X2 due to the opposing nature of depth versus areal extent (Figures 11a, 11b, and 11c). Many ecological processes within estuarine habitat depend on the depth, area, and volume of the LSZ and its proximity to various habitats and stressors, which 3D models can fairly accurately and precisely predict. Deeper areas support gravitational circulation, shallow areas expose more of the water column to the photic zone, etc. Unlike the one-dimensional X2 approach, the 3D models lend themselves to the construction of predictive models of ecological processes.



Figures 11a, 11b & 11c. Average area, depth, and volume of the LSZ at 1 km changes in X2.

Appendix 3: Review of Scientific Papers and Summary of Key Findings

BEGINS ON FOLLOWING PAGE

DRAFT

Review of Scientific Papers and Summary of Key Findings

For the ASC-EPA Technical Workshop on
Estuarine Habitat in the Bay Delta Estuary

AQUATIC SCIENCE CENTER

Prepared for
U.S. Environmental Protection Agency
March 2012

Thomas Jabusch
Aquatic Science Center

PAGE INTENTIONALLY LEFT BLANK

Building a Common Library of Scientific Papers

This document summarizes the key findings of selected technical papers on X2, the low salinity zone, and the ecological community of the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay Delta Estuary). The Aquatic Science Center (ASC) prepared the summary to support the technical workshop on estuarine habitat being staged in Sacramento on 27 March 2012 by ASC and EPA. This summary is accompanied by a common library of online scientific papers that workshop participants will be able to access before, during, and after the workshop. ASC analyzed papers in this library to identify common themes, key points of agreement and disagreement (and reasons thereof), and uncertainties.

The common library was built through a relatively informal process. As a starting point, Dr. Bruce Herbold offered an initial list of thirty-six (36) "essential" LSZ/X2 papers produced since 1995. This became known as the "long-list" of papers that provided a useful reference tool to subsequent reviewers of the list. Based on the long-list, Dr. Wim Kimmerer kindly suggested a shorter, more manageable set of papers, and this became known as the "short list." Dr. Kimmerer used the following criteria for selecting a paper for the short list: the paper (1) applies in particular to the low-salinity zone, or to species resident there; and (2) either provides a good overview of the habitat, or provides new looks at particular aspects of that habitat.

Drs. Anke Mueller-Solger and Matt Nobriga graciously reviewed both lists and added their own recommendations. Each scientist arrived at a slightly different list of essential papers, and all agreed that the task was difficult and depended upon the selection criteria for inclusion. Given time constraints, prospective workshop participants were not surveyed about the selection criteria, and ASC and EPA were willing to accept the basic criteria established by Dr. Kimmerer and the collective, best professional judgment of Drs. Herbold, Mueller-Solger, and Nobriga. The final list of 23 papers provided here represents a hybrid of the "desert island" lists that were provided by each expert. The workshop planning team[206] accepted these papers as those most likely to garner the greatest acceptance among workshop participants for their characterization of ecological processes and hydrodynamics pertaining to X2 and the low salinity zone.

206 Members of the Planning Team for the Estuarine Workshop
Brock B. Bernstein, Ph.D., workshop facilitator under contract with Aquatic Science Center
Erin Foresman, Environmental Scientist & Policy Coordinator, EPA Region 9
Bruce Herbold, Ph.D., EPA Region 9
Thomas Jabusch, Ph.D., Aquatic Science Center
Tim Vendlinski, Senior Policy Advisor, EPA Region 9

Summary of Key Findings

There are well-accepted statistical relationships between the abundance and survival of fishes and other estuarine species with the location of the low salinity zone (LSZ), as represented by X2 (the 2% bottom salinity position). However, there is a need to more extensively study causal relationships among X2, estuarine habitat quality, and fish populations.

Agreements

The following statements represent general consensus of the science community, as represented in the peer-reviewed literature pertaining to the LSZ or X2:

Habitat

Abundance of Zooplankton and Young Fishes is Centered Near or Slightly Upstream of the LSZ. Bennett et al. (2002), Jassby et al. (1995), Kimmerer et al. (2002), Moyle et al. (1992).

Low Salinity Habitat Distributed Over Shoal Areas Is More Productive and Provides Better Rearing Conditions Than Habitat Confined to Deeper Channels. Overall, the historical sampling record indicates that delta smelt have remained several fold more abundant in northern Suisun Bay and Suisun Marsh channels than in southern Suisun Bay and the Delta. There also appears to be a link between the recruitment success for delta smelt and the availability of shallow-water habitats rather than the amount of freshwater outflow alone (as indexed by X2). Bennett (2005), Bennett et al. (2002), Moyle et al. (1992).

Delta Smelt Habitat Extent. Delta smelt is endemic to the estuary; habitat extends from the tidal freshwater reaches of the Delta seaward to about 19 psu salinity at water temperatures lower than 25°C. Bennett (2005).

Habitat for Northern Anchovy Is Negatively Related to X2. When the Asian clam *Corbula amurensis* invaded the San Francisco Estuary in 1986, the distribution of northern anchovy (*Engraulis mordax*), the most common fish in the estuary, shifted toward higher salinity, reducing summer abundance in the LSZ by 94%. The response of the anchovy to the arrival of *Corbula* was rapid, manifested in a sharp decline in summer abundance from 1986 to 1987. The resulting shift in the anchovy's spatial distribution in the estuary appears to have been a direct behavioral response to reduced food (i.e., reduction in overall biomass and replacement of preferred zooplankton species by invasives, as indicated by carbon biomass estimates). Although the abundance of northern anchovy has declined in the low salinity zone, it still dominates the biomass of fish in the more saline reaches of the estuary. The bulk of the anchovy population even before the decline was at high salinity: 95% of the catch before 1987 occurred at salinities greater than 10%.

The disappearance of the northern anchovy from the LSZ may have allowed more successful foraging of remaining species, especially delta smelt and longfin smelt. Northern anchovy is a filter feeder, food density-dependent feeder and thus may be more sensitive to changes in the abundance of their prey than smelt, which are "picking type" of feeders whose feeding success is more of a density independent, or density vague process.

Bennett (2005), Kimmerer (2006).

Fish Populations

The Pelagic Organism Decline (POD): Populations of Four Pelagic Fishes Suddenly Declined in the Early 2000s. Change point models detected step declines in abundances of delta smelt, longfin smelt, striped bass, and threadfin shad in the early 2000s, with a likely common decline in 2002. However, no single factor emerged to explain the POD (see Uncertainties), which is now believed to be the result of multiple effects. Abiotic habitat factors relate directly and indirectly to the declining fish abundances. The conclusion is based on univariate and multivariate analyses of the effects of abiotic habitat variables, in particular X2 and water clarity. Abiotic habitat factors can affect fish by directly increasing or decreasing the extent of their physical habitat and indirectly by impacting their prey or predators. Bennett (2005), Mac Nally et al. (2010), Thomson et al. (2011).

Delta Smelt and Striped Bass Are More Abundant in More Turbid Waters. Based on generalized additive modeling results, the predicted occurrence of delta smelt and striped bass decreased as Secchi depth increased. Feyrer et al. (2007).

Young Fishes And Zooplankton Can Actively Maintain Position Within the LSZ. Young fishes migrated vertically and maintained position in the LSZ, switching between two strategies depending on freshwater flow and longitudinal position of the LSZ. Zooplankton in the LSZ also migrate vertically with the tides to maintain position, but there are differences among years and between taxa. Bennett et al. (2002), Kimmerer et al. (1998), Kimmerer et al. (2002).

Delta Smelt Is at Risk of Extinction. Limited distribution, short life span, low reproductive capacity, as well as relatively strict abiotic habitat and feeding requirements, are indications that delta smelt is at catastrophic risk in a fluctuating environment. A small percentage (<10%) lives two years and may have an important influence on population dynamics by augmenting spawning success after years of poor recruitment. Bennett (2005).

Flow Response

The Abundance of Several Common Species of Fish Varies Positively With Flow Entering the Estuary, as Indexed by X2. Based on data collected through 1992, Jassby et al. (1995) presented simple and significant statistical relationships of X2 with annual measures of phytoplankton-derived detritus from river loading; mollusks; mysids (*Neomysis mercedis*); bay shrimp (*Crangon franciscorum*); larval fish survival; and the abundance of longfin smelt (planktivorous), striped bass (piscivorous), and starry flounder (bottom-foraging). The abundance of most of these fish and the shrimp species is elevated in years when mean spring and early summer (April – July) X2 locations are moved seaward (closer to the Golden Gate) by high Delta outflows. The starry flounder abundance index responds to spring X2 in the previous year.

There are also notable exceptions. For example, delta smelt abundance does not correspond to X2. However, Bennett (2005) notes that the abundance of delta smelt is elevated only in years when the low salinity zone is located in Suisun Bay.

Adding 7 to 8 yr of post-*Corbula* data (based on availability) to those previously analyzed by Jassby et al. (1995), Kimmerer (2002) found that most of the species that were responsive to flow before *Corbula*'s arrival continue to have statistically demonstrable linkages between abundance or early life stage survival and X2 position. Kimmerer's analyses confirmed that all of the fish and shrimp, except delta smelt, had negative relationships with X2, indicating higher abundance at high flow. Two of them, starry flounder and longfin smelt, had negative relationships with X2 with no significant change in slope before and after 1987 but with lower intercepts after 1987, indicating 4-fold declines in overall abundances after the arrival of *Corbula*. The bay shrimp *Crangon franciscorum* had a significant relationship with X2 that had not appeared to change since 1988, although both the lowest and highest residuals around the X2 trend line were observed after 1988, indicating a possible transient response either to the change in the food web or to the extended drought from 1985 to 1992. Exceptions to this overall trend of continuity were the response of delta smelt and the mysid shrimp *Neomysis mercedis*. The latter was previously abundant in the LSZ in summer but declined about 50-fold after 1987. The response of *N. mercedis* to X2 changed significantly between the two periods, with a negative slope through 1987 (higher at high flow) and a steep positive slope thereafter (higher at low flow). Regressions on delta smelt abundance index data from 1975 – 1999 for two time periods (1975 – 1981 and 1981 – 1999) showed a positive relationship with X2 during the period up to 1981 and a negative but non-significant relationship from 1982 on.

Although X2 is not equivalent to flow, it still reflects the large interannual variability in river flow. Daily, monthly, and seasonal time series regressions demonstrate strong relationships between X2 and Delta outflow. $X2 \sim Q^{1/7}$, based on more than 20 years of data in which flow varies by a factor of approximately 200.

Jassby et al. (1995), Kimmerer (2002), Monismith et al. (2002), Moyle et al. (1992), Nobriga et al. (2008).

Organic Carbon Supply Increases With Flow. The supply rate of organic carbon to the Estuary increases with increasing freshwater flow, mainly because of river-borne inputs. However, much of the organic carbon in wet years is wood and thus less bioactive. Herbold (pers. comm.), Jassby et al. (1995).

Foodweb

Lack of Phytoplankton Blooms in the Upper Estuary. In the two most recent decades, phytoplankton blooms have been rare in the Estuary although nutrient concentrations are high. Blooms in the estuary were common in earlier years, despite higher turbidity. Alpine and Cloern (1992), Dugdale et al. (2007).

***Corbula* Caused a Major Change in the Food Web.** Chlorophyll a and several species of zooplankton (including mysids and some copepods) declined markedly after 1987. Mysids declined by about half and declines in some copepod species were accompanied by increases in other, introduced species. These introduced species are of lower nutritional value (e.g. omega fatty acid content). The now dominant exotic copepod, *Limnoithona tetraspina*, is also much smaller than the species it replaced, requiring planktivores to "work harder" to capture equivalent quantities of food. Bennett (2005), Herbold (pers. comm.), Kimmerer (2002), Kimmerer (2006).

Low Salinity Zone

The Salinity Field Embodies Information Not Directly Or Solely Related to the Chemical Properties of Water. The amount of freshwater flow into the Estuary is reflected in the salinity distribution, which in turn may determine the geographic location of estuarine turbidity maxima, entrapment phenomena, or null zones. For example, variation in gravitational circulation at a longer time scale may occur due to movement of the LSZ in response to variation in freshwater flow. Jassby et al. (1995), Peterson et al. (1975).

The LSZ Forms Multiple Turbidity Maxima of Various Origins. In the varying bathymetry of northern San Francisco Bay, the LSZ can move between shallow and deep water, altering the propensity for gravitational circulation to occur and producing multiple turbidity maxima that are positioned by bottom topography instead of salinity. Gravitational circulation is dependent on depth and more frequently observed in the deeper water column of Carquinez Strait, compared to shallower areas. Bennett et al. (2002), Kimmerer et al. (2002), Schoellhamer (2001).

Habitat Models

Habitat Volume is Highly Correlated With Surface Area. Kimmerer et al. (2009) simulated habitat volume using the TRIM3D hydrodynamic model and found that slopes of habitat volume vs. X2 were highly correlated with slopes of habitat area vs. X2 ($r^2 = 0.97$). Feyrer et al. (2011), Kimmerer et al. (2009).

Disagreements

Habitat

Best Method for Examining and Predicting Habitat Use. Both Kimmerer et al. (2009) and Feyrer et al. (2011) employed General Additive Modeling (GAM) to predict habitat use by estuarine fish. Kimmerer et al. (2009) employed habitat curves based on catch per trawl, because they were usually closer to the underlying fish distributions than those based on frequency of occurrence, which they argue tended to be extremely skewed. Feyrer et al (2011) chose to model frequency of occurrence rather than catch per trawl, as they argue, to minimize the possible influence of outliers and bias associated with long-term abundance declines. Feyrer et al. (2011), Kimmerer et al. (2009).

Flow Response

Fish Responses to X2 Remain a Topic of Debate. Kimmerer et al. (2009) observed that abundance –springtime X2 relationships correspond with habitat volume-springtime X2 relationships for striped bass, but not for delta smelt, longfin smelt, or in fact, most of the other species examined. These findings imply that increasing quantity of habitat, as defined by salinity, cannot explain the X2 relationships for most of the species and suggests that other mechanisms may be more or equally important. For example, the abundance index of longfin smelt varied by about two orders of magnitude over the range of X2 values, whereas the observed modest slope of habitat to X2 would allow for only about a twofold variation in abundance index over that X2 range. Kimmerer et al. (2009) conclude that increases in quantity of habitat may contribute to longfin smelt's strong X2 relationship, but that the mechanism chiefly responsible for it remains unknown.

Feyrer et al. and Nobriga et al. (2008) suggest that for delta smelt, the relationship between X2 and abundance is not apparent, because the delta smelt population may be responding to spatial scales smaller than other, more widely distributed species. They also conclude that delta smelt respond to regional salinity patterns through time, and specifically to conditions that occur seasonally in summer and fall. They imply that the springtime X2 (January – June) used by Kimmerer et al. (2009) and Bennett (2005) may not be expected to predict the abundance of delta smelt, due to the fact that these fish, due to other limiting factors, may not arrive in the LSZ until late spring or early summer. Nobriga et al. (2008) found that salinity predicted delta smelt occurrence in summer in three distinct geographic regions (Suisun Bay, Sacramento-San Joaquin River confluence, and San Joaquin Delta) that had similar long-term trends in delta smelt capture probabilities. Through generalized additive modeling, Feyrer et al. (2007) concluded that the combined effects of fall stock abundance and water quality (i.e., salinity and water clarity), predicted recruitment abundance in the following summer, at least during the past two decades, when food availability was severely reduced by *Corbula*.

Bennett (2005), Feyrer et al. (2007), Jassby et al. (1995), Kimmerer (2002), Kimmerer et al. (2009), Nobriga et al. (2008).

Foodweb

Decline in Phytoplankton Biomass. The downward trend in phytoplankton biomass over the last few decades is combined with "demographic" changes in the phytoplankton community from large diatoms to flagellates, blue-green algae, and smaller species of diatoms. The drivers of the algal trends are still being debated. The large decline in phytoplankton biomass (as measured by chlorophyll a) in Suisun Bay occurred mostly after the introduction of *Corbula* in 1986. The overall decline in phytoplankton biomass came hand in hand with a decline in the proportion of diatoms. Several other drivers are thought to play a role in the observed changes to the algal community. Among them are increased ammonia loadings, water diversions, and a reduction in phosphorus loadings.

Earlier observations that phytoplankton has rebounded in the Delta in the late 90s seem to be confounded by more recent data indicating a continuation of the long-term decline. Baxter et al. (2010), Bennett and Moyle (1996), Brown (2009), Dugdale et al. (2007), Jassby (2008), Jassby et al. (2002), Kimmerer (2002), Kimmerer (2005), Van Nieuwenhuyse (2007), Winder & Jassby (2010).

Decline in Productivity. Since the mid-1970s, the upper Estuary had experienced declines in phytoplankton biomass, zooplankton abundance, and fish populations. Whether or not these declines are driven by declines in primary productivity and consecutive trophic changes remains a topic of debate. For example, based on the findings by Dugdale et al. (2007), ammonium (NH_4) may decrease primary productivity by inhibiting algal growth (Dugdale et al. 2007). Others hypothesize that NH_4 may be shifting primary productivity to *Microcystis*, blue-green algae of less nutritional value (Glibert 2010). On the other hand, clams are believed to capture and largely redirect productivity from the pelagic to the benthic foodweb, not necessarily resulting in a decline in primary productivity overall (Kimmerer 2002). And then again, extensive grazing by clams may deplete populations of phytoplankton to the point where primary productivity is getting reduced. However, the main conclusion drawn by Kimmerer (2002) was that the decrease in the abundance of phyto- and zooplankton was not associated with trends in fish, thus implying that fish declines are not driven by trophic changes. Dugdale et al. (2007), Glibert (2010), Kimmerer (2002)

Uncertainties

Habitat

Our Picture of Abiotic Habitat Condition Is Limited. Salinity, water clarity, and temperature are important water quality variables but don't fully define abiotic habitat. Additional information is needed to better define the mechanisms that mediate the effects of water quality variables on aquatic organisms. This also requires a more complete understanding of how the direct effects of water exports interact with the indirect effect of affecting abiotic conditions and the food web. Bennett (2005), Feyrer et al. (2007); Jassby et al. (1995), Kimmerer (2002), Kimmerer et al. (2009), Nobriga et al. (2008), Mac Nally et al. (2010).

Future Habitat Trends Are Uncertain. There is high uncertainty about future trends in factors that are likely to influence habitat suitability, such as future precipitation, sea level rise, additional invasive species, catastrophic natural events, or future policy directions. Bennett (2005), Feyrer et al. (2007), Nobriga et al. (2008).

Causal Relationships Between the Hydrodynamics of the LSZ and the Abundance and Distribution of Young Fishes Remain Largely Unresolved. Jassby et al. (1995), Nobriga et al. (2008).

Data Are Limited on Many Potential Factors Affecting Habitat Suitability. Many potential factors may affect habitat suitability, including food density, entrainment risk, predation risk, or exposure to contaminants. Data on such factors are limited. Interactions between abiotic and biotic habitat components can affect vital rates (per capita birth, death, fecundity) and exert density-dependent effects on population dynamics, although such relationships are currently poorly understood. Bennett (2005), Feyrer et al. (2007), Feyrer et al. (2011), Mac Nally (2010).

Macrophyte Proliferation May Adversely Affect Pelagic Fishes. The invasion of aquatic macrophytes has already substantially changed near-shore fish assemblages and may also have restricted pelagic fish distributions. In particular, the invasive Brazilian waterweed (*Egeria densa*) increases water clarity by trapping suspended sediments, thus negatively affecting native and desirable pelagic fishes. Furthermore, piscivorous yearling striped are typically found in shallower channels that are now subject to increasing density of *Egeria* beds. This may have implications on the result of abundance and possibly changes in available prey items. The association with *Egeria* beds may also skew abundance indices, since fish in shallow water with dense vegetation are less susceptible to being caught in the Fall Midwater Trawl on which these estimates are based. Feyrer et al. (2007), Herbold (pers. comm.), Nobriga et al. (2005, 2008).

Fish Populations

Vertical and Horizontal Distribution Patterns of Zooplankton and Fishes Are Not Fully Understood. There are differences among years and variability among taxa in the tidal movements of zooplankton and fishes in the LSZ that are not fully explained. The migratory behavior of copepods is not consistent with, but also not responsive to, changes in freshwater flow, salinity, or stratification. In the Suisun Bay ship channel, most fishes and zooplankton appeared to undergo tidal vertical migrations, occurring near the surface during flood tides and at depth on ebbs. However, in Suisun Cut some fishes, including delta smelt, appeared to undergo reverse diel migrations, remaining near the surface during the day and at depth during the night. Delta smelt post-larvae in freshwater portions of the Sacramento and San Joaquin rivers were significantly more abundant at depth during the day relative to night, but the results are difficult to interpret without accompanying hydrodynamic information. The mechanisms responsible for variability in migration behaviors remains unclear as are the potential benefits gained by maintaining position in the LSZ. Bennett et al. (2002), Kimmerer (2002), Kimmerer et al. (2002), Bennett (2005).

Short List of Key Papers on X2 and the Low Salinity Zone since 1995

1995

1. Jassby AD, Kimmerer WJ, Monismith SG, Armor C, Cloern JE, Powell TM, Schubel JR, Vendlinski TJ. 1995. Isohaline position as a habitat indicator for estuarine applications. Ecological Applications 5(1): 272-289.

2001

2. Schoellhamer, DH. 2001. Influence of salinity, bottom topography, and tides on locations of estuarine turbidity maxima in northern San Francisco Bay. Coastal and Estuarine Fine Sediment Processes. Elsevier, Amsterdam, The Netherlands.

2002

3: Kimmerer WJ, Bennett, WA, Burau JR. 2002. Persistence of tidally-oriented vertical migration by zooplankton in a temperate estuary. Estuaries 25: 359-371.

4: Bennett WA, Kimmerer WJ, Burau JR. 2002. Plasticity in vertical migration by native and exotic estuarine fishes in a dynamic low-salinity zone. Limnology and Oceanography 47: 1496-1507.

5: Monismith SG, Kimmerer WJ, Burau JR, Stacey MT. 2002. Structure and flow-induced variability of the subtidal salinity field in northern San Francisco Bay. Journal of Physical Oceanography 32: 3003-3019.

6: Kimmerer WJ. 2002. Effects of freshwater flow on abundance of estuarine organisms: physical effects or trophic linkages? Marine Ecology and Progress Series 243: 39-55.

2004

7: Ruhl CA, Schoellhamer DH. 2004. Spatial and temporal variability of suspended-sediment concentrations in a shallow estuarine environment. San Francisco Estuary and Watershed Science 2(2): 1.

2005

8: Kimmerer WJ. (2005. Long-term changes in apparent uptake of silica in the San Francisco estuary. Limnology and Oceanography 50: 793-798.

9: Bennett WA. 2005. Critical assessment of the delta smelt population in the San Francisco Estuary, California. San Francisco Estuary and Watershed Science 3(2): 1.

2006

10: Hobbs JA, Bennett WA, Burton JE. 2006. Assessing nursery habitat quality for native smelts (*Osmeridae*) in the low-salinity zone of the San Francisco Estuary. Journal of Fish Biology 69: 907-922.

11: Kimmerer WJ. 2006. Response of anchovies dampens effects of the invasive bivalve Corbula amurensis on the San Francisco Estuary foodweb. Marine Ecology Progress Series 324: 207-218.

2007

12: Dugdale RC, Wilkerson FP, Hogue VE, Marchi A. 2007. The role of ammonium and nitrate in spring bloom development in San Francisco Bay. Estuarine, Coastal and Shelf Science 73(1-2): 17-29.

13: Feyrer F, Nobriga ML, Sommer TR. 2007. Multi-decadal trends for three declining fish species: habitat patterns and mechanisms in the San Francisco Estuary, California, USA. Canadian Journal of Fisheries and Aquatic Sciences 64(4): 723-734.

2008

14: Nobriga M, Sommer T, Feyrer F, Fleming K. 2008. Long-term trends in summertime habitat suitability for delta smelt, *Hypomesus transpacificus*. San Francisco Estuary and Watershed Science 6(1): 1.

15: Jassby AD. 2008. Phytoplankton in the Upper San Francisco Estuary: recent biomass trends, their causes and their trophic significance. San Francisco Estuary and Watershed Science 6(1): 2.

2009

16: Kimmerer WJ, Gross ES, MacWilliams ML. 2009. Is the response of estuarine nekton to freshwater flow in the San Francisco Estuary explained by variation in habitat volume? Estuaries and Coasts 32: 375-389.

17: Enright C, Culberson SD. 2009. Salinity trends, variability, and control in the northern reach of the San Francisco Estuary. San Francisco Estuary and Watershed Science, 7(2): 3.

2010

18: Mac Nally R, Thomson JR, Kimmerer WJ, Feyrer F, Newman KB, Sih A, Bennett WA, Brown L, Fleishman E, Culberson SD, Castillo G. 2010. An analysis of pelagic species decline in the upper San Francisco Estuary using multivariate autoregressive modeling. Ecological Applications 20(5): 1417-1430.

19: Thomson JR, Kimmerer WJ, Brown LR, Newman KB, Mac Nally R, Bennett WA, Feyrer F, Fleishman E. 2010. Bayesian change point analysis of abundance trends for pelagic fishes in the upper San Francisco Estuary. Ecological Applications 20(5): 1431-1448.

2011

20: Feyrer F, Newman K, Nobriga M, Sommer T. 2011. Modeling the effects of future outflow on the abiotic habitat of an imperiled estuarine fish. Estuaries and Coasts 34: 120-128.

21: York J, Costas B, McManus G. 2010. Microzooplankton grazing in green water—results from two contrasting estuaries. Estuaries and Coasts 34: 373-385.

22: Winder M, Jassby AD. 2011. Shifts in zooplankton community structure: implications for food web processes in the upper San Francisco Estuary. Estuaries and Coasts 34: 675-690.

23: Schoellhamer DH. 2011. Sudden clearing of estuarine waters upon crossing the threshold from transport to supply regulation of sediment transport as an erodible sediment pool is depleted: San Francisco Bay, 1999. Estuaries and Coasts 34: 885-899

Summaries

1: Isohaline position as a habitat indicator for estuarine populations
Author(s): A. D. Jassby, W. J. Kimmerer, S. G. Monismith, C. Armor, J. E. Cloern, T. M. Powell, J. R. Schubel, and T. J. Vendlinski
Year: 1995
Journal: Ecological Applications
Volume: 5
Number: 1
Pages: 272-289
URL: http://sfbay.wr.usgs.gov/publications/pdf/jassby_1995_isohaline.pdf
Relevance to X2 and LSZ: This paper reports the scientific basis of using X2 (the 2% bottom salinity position) as a habitat indicator to regulate freshwater flow to the Bay Delta Estuary. Participants in EPA's initial estuarine habitat workshop recommended that standards for protecting aquatic life should be based at least in part on the estuary's physical response to fluctuations in freshwater input, i.e., on some "habitat indicator" (sensu Messer 1990, who defines habitat indicator as a "physical attribute measured to characterize conditions necessary to support an organism, population, or community in the absence of pollutants"). The salinity field was of particular interest, and X2 was found to be particularly valuable because by knowing X2 only, one can recreate the entire mean salt field in the Estuary. Additional advantages include that it can be measured with greater accuracy and precision then net freshwater inflow into the estuary. At the same time, statistical analyses demonstrate an unambiguous relationship of X2 with net Delta outflow. The recommendation for X2 as a habitat indicator are based on statistical relationships with year-to-year variability in multiple estuarine resources, including phytoplankton, mollusks, and fish. In the case of fish, clear and pervasive relationships are demonstrated with bottom-foraging fish (starry flounder) and both survival (striped bass) and abundance (longfin smelt and striped bass) of fish that feed in the water column. There is also a clear and pervasive relationship between X2 and phytoplankton-derived particulate organic carbon (POC). The response of the mollusk community is more distinctive. The mollusk abundance index, expressed as the total mollusk density in Grizzly Bay, showed a clear minimum at intermediate values of X2.

2: Influence of salinity, bottom topography, and tides on locations of estuarine turbidity maxima in northern San Francisco Bay
Author(s): D. H. Schoellhamer
Year: 2001
Book: Coastal and Estuarine Fine Sediment Processes
Editor(s): W. H. McAnally and A. J. Mehta
Publisher: Elsevier, Amsterdam, Netherlands
Pages: 373-385
URL: http://sfbay.wr.usgs.gov/sediment/elsevierPDF.html
Relevance to X2 and LSZ: The purpose of this paper is to describe how salinity, bottom topography, and tides influence the locations of the estuarine turbidity maximum (ETM), or suspended sediment concentration (SSC) maxima, in northern San Francisco Bay. ETMs form when salinity is present but they are not associated with a singular salinity. In San Francisco Bay, there is a larger salinity range for ETM location than is observed in other estuaries. The processes that account for a salinity-dependent ETM include gravitational circulation, salinity stratification, and bed storage. The longitudinal salinity gradient, not salinity, creates gravitational circulation and ETMs. All these processes occur in northern San Francisco Bay and are modified by bottom topography and tides. Bottom topography enhances salinity stratification, gravitational circulation, and ETM formation seaward of sills.

Salinity stratification in Carquinez Strait, which is seaward of a sill, is greatest during neap tides, which are the only times when tidally averaged SSC in Carquinez Strait was less than that observed landward at Mallard Island. Maximum bottom SSC measured by USGS water quality cruises was located in Carquinez Strait 67 percent of the time, and tidally averaged SSC was greater in Carquinez Strait and the Reserve Fleet Channel, which are both seaward of sills, compared with more landward sites.

3: Persistence of tidally oriented vertical migration by zooplankton in a temperate estuary
Author(s): W. J. Kimmerer, W. A. Bennett, and J. R. Burau
Year: 2002
Journal: Estuaries
Volume: 25
Number: 3
Pages: 359-371
URL: http://www.springerlink.com/content/g55tp2lx7x3r5v66/fulltext.pdf
Relevance to X2 and LSZ: Results from this study show differences among years and variability among taxa in the tidal movements of zooplankton species in the LSZ. The authors demonstrate extensive evidence showing some degree of persistence of various behaviors but were unable to determine how these translate to position maintenance. Based on the presented results, the variable bathymetry in the northern Estuary may play a key role in position maintenance. The migratory behavior of copepods was not consistent and also not responsive to changes in freshwater flow, salinity, or stratification. By contrast, mysids and amphipods responded to freshwater flow regimes. The results for copepods suggest rigid behavior regardless of changing environmental variables, whereas mysids and amphipods altered their behavior depending on local conditions related to freshwater flow. The zooplankton species differed in salinity range. The authors also observed a landward shift of the center of abundance of the copepod *Eurytemora affinis*, which appears to have coincided with the spread of the introduced clam *Potamocorbula amurensis*. They also determined that, since 1988, chlorophyll concentration has been lower in the LSZ compared to the freshwater Delta. During 1988-1998, chlorophyll was generally about 3-fold to 10-fold lower than previously for salinity values between 0.5 and 20 psu, and a consistent and occasionally steep spatial gradient was observed with higher chlorophyll at salinity values below 1 psu.

4: Plasticity in vertical migration by native and exotic estuarine fishes in a dynamic low-salinity zone
Author(s): W. A. Bennett, W. J. Kimmerer, and J. R. Burau
Year: 2002
Journal: Limnology and Oceanography
Volume: 47
Number: 5
Pages: 1496-1507
URL: http://www.aslo.org/lo/toc/vol_47/issue_5/1496.html
Relevance to X2 and LSZ: This paper examines the degree of flexibility in retention strategies of young fishes in the LSZ during years of highly variable river flow. Young fishes migrated vertically and maintained position in the LSZ, switching between two strategies depending on freshwater flow and longitudinal position of the LSZ. Abundances of four fish species (delta smelt, longfin smelt, striped bass, yellowfin goby) and estimated volume of detrital material were highest at the lower end of the range of salinity sampled in the LSZ. These results support previous observations (see, for example Moyle et al. 1992) showing that an assemblage of young fishes occupies the turbid landward margin of the LSZ. In 1994, striped bass, longfin smelt, and yellowfin goby migrated tidally, occurring near the surface on flood tides and near the bottom on ebb tides. During 1995, this behavior persisted for striped bass and yellowfin goby, even though landward residual currents were present under high river-flow conditions. In contrast, during moderate freshwater flow conditions when the LSZ

was positioned in the morphologically complex central Suisun Bay, fishes exhibited reverse diel migrations at the north channel sites such that they were more abundant at the surface by day and at depth by night. The authors suggest that vertical migrations may enhance feeding success, because zooplankton prey similarly migrated in the LSZ.

5: Structure and flow-Induced variability of the subtidal salinity field in northern San Francisco Bay
Author(s): S. G. Monismith, W. J. Kimmerer, J. R. Burau, and M. T. Stacey
Year: 2002
Journal: Journal of Physical Oceanography
Volume: 32
Pages: 3003-3019
URL: http://www-ce.stanford.edu/faculty/monismith/MonismithEtAl2002JPO.pdf
Relevance to X2 and LSZ: This paper provides new insights into the salinity distribution (geographically and over time) of the estuary as it relates to X2. It discusses the structure of the salinity field in northern San Francisco Bay and how it is affected by freshwater flow. Analysis of covariability of Q and X showed a characteristic timescale of adjustment of the salinity field of approximately 2 weeks in response to flow. X2 was found to be proportional to riverflow to the 1/7 power. Thus, the (geographical) length of salinity intrusion into the northern estuary turns out to be relatively insensitive to river flow. The authors argue that the relatively weak dependence of salinity intrusion on flow is owed to dynamic tidal variations, which modulate stratification in the northern estuary. Regardless, they find that X2 can be used as an unambiguous flow-dependent length (as in "distance") scale for salinity intrusion, based on the relationship of $X2 \sim Q^{1/7}$. A key finding from the analysis is a self-similar distribution (whole curve has similar shape as it parts) of depth-averaged salinity in the estuary that is proportional to 1/X2, with a salinity gradient in the center 70% of the region between the Golden Gate and X2. For improving vertically resolved models of salinity intrusion (circulation models), accurately modeling the effects of stratification may be key.

6: Effects of freshwater flow on abundance of estuarine organisms: physical effects or trophic linkages?
Author(s): W. J. Kimmerer
Year: 2002
Journal: Marine Ecology Progress Series
Volume: 243
Pages: 39-55
URL: http://www.waterrights.ca.gov/baydelta/docs/exhibits/DOI-EXH-33I.pdf
Relevance to X2 and LSZ: Kimmerer posits that variations in the abundance or survival of fish in the northern estuary may occur through attributes of physical habitat that vary with flow. Based on reexamining responses of estuarine species to flow and changes in the foodweb (caused by the invasion of *Potamocorbula amurensis*), he concludes variation with freshwater flow of abundance or survival of organisms in higher trophic levels apparently did not occur through upward trophic transfer. All but 3 of the examined species had median salinity between 0.5 and 6, i.e. their distributions overlapped substantially with the LSZ, but large parts of their populations are outside of the LSZ. Fish (with the exception of delta smelt) and shrimp responded positively to flow, whereas chl a (i.e., phytoplankton) and several species of zooplankton had either weak responses to flow or responses that changed after the arrival of *P. amurensis* in 1987. Following the spread of *P. amurensis,* there is a marked decreasing trend in organic matter production and plankton abundance with time, but fish and shrimp did not appear to respond to this change.

7: Spatial and temporal variability of suspended sediment concentrations in a shallow estuarine environment
Author(s): C. A. Ruhl and D. H. Schoellhamer
Year: 2004

Journal: San Francisco Estuary and Watershed Science
Volume: 2
Number: 2
Pages: Article 1
URL: http://escholarship.org/uc/item/1g1756dw#page-1
Relevance to X2 and LSZ: Sediment transport shallow water differs from that in deeper channels because of greater wind wave resuspension, closer proximity to the shore and tributaries, and greater relative benthic filtering. The U.S. Geological Survey measured suspended-sediment concentrations at five locations in Honker Bay, a shallow subembayment of San Francisco Bay, and the adjacent channel to investigate the spatial and temporal differences between deep and shallow estuarine environments. During the first freshwater pulse of the wet season, the channel tended to transport suspended sediments through the system, whereas the shallow area acted as off-channel storage where deposition would likely occur. Following the freshwater pulse, suspended-sediment concentrations were greater in Honker Bay than in the adjacent deep channel, due to the larger supply of erodible sediment on the bed. However, the tidal variability of suspended-sediment concentrations in both Honker Bay and in the adjacent channel was greater after the freshwater pulse than before. During wind events, suspended-sediment concentrations in the channel were not affected; however, wind played a crucial role in the resuspension of sediments in the shallows.

8: Long-term changes in apparent uptake of silica in the San Francisco Estuary
Author(s): W. J. Kimmerer
Year: 2005
Journal: Limnology and Oceanography
Volume: 50
Number: 3
Pages: 793-798
URL: http://www.aslo.org/lo/toc/vol_50/issue_3/0793.html
Relevance to X2 and LSZ: Kimmerer used silica distributions in the northern estuary to infer the apparent uptake of silica and diatom production. Primary production estimated from dissolved silica uptake was similar to production estimated from light and chlorophyll. Production based on dissolved silica (Si_d) averaged 1% and 17% of values prior to the introduction of *P. amurensis*. The Si uptake rates are calculated with a steady-state flux model based on measured salinity gradients and calculated hydraulic residence times. Mixing curves validate the Si-salinity relationship over a range of flow conditions but indicate a slightly negative trend in flow, particularly in June, reflecting the declining hydrograph in the transition from the spring high-flow period to the dry season. However, there is no evidence for an influence of either freshwater flow or temperature, and therefore climate change, on the long-term trend in diatom production.

9: Critical assessment of the delta smelt population in the San Francisco Estuary, California
Author(s): W. A. Bennett
Year: 2005
Journal: San Francisco Estuary and Watershed Science
Volume: 3
Number: 2
Pages: Article 1
URL: http://escholarship.org/uc/item/0725n5vk
Relevance to X2 and LSZ: Delta smelt was formally abundant in the low-salinity and freshwater habitats of the northeastern San Francisco Estuary but is now listed as threatened under the Federal and California State Endangered Species Acts. A key area of controversy centers on impacts to delta smelt associated with exporting large volumes of freshwater from the estuary to supply California's significant agricultural and urban water demands.

Uncertainties about the impacts of water export operations on the delta smelt population range from limited knowledge of the numbers of larvae lost in exported water, and impacts of predators near the facilities, to the conditions promoting significant entrainment events at all life stages. Use of a population model suggests that water export operations can impact the abundance of post-larval (about 20 mm fork length) delta smelt, but these effects may not reflect on adult abundance due to other processes, such as impacts of toxic chemicals or changes to the estuarine foodweb by exotic species. Limited work to date has not shown a significant impact of toxic chemicals on delta smelt, however, the author sees a real threat considering the rapidly evolving development and use of new pesticides. Impacts due to exotic species are likely, but there are large uncertainties, in part due to the complexity of interference with delta smelt recruitment. In comparison with other fish, delta smelt has a tiny geographic range being confined to a thin margin of low salinity habitat in the estuary. It is a small and primarily annual species but with low fecundity and a protracted spawning season: key traits that are typically associated with a perennial life history strategy. Delta smelt also do not appear to compensate for their limited reproductive capacity by having precocious offspring; their larvae are pelagic. Overall, the population persists by maximizing growth, survival, and reproductive success on an annual basis despite an array of limiting factors that can occur at specific times and locations. However, population viability analysis using delta smelt abundance estimates for the entire data record (1982–2003) suggest a high probability that the population would decline post 2004.

10: Assessing nursery habitat quality for native smelts (*Osmeridae*) in the low-salinity zone of the San Francisco Estuary
Author(s): J. A. Hobbs, W. A. Bennett, and J. E. Burton
Year: 2006
Journal: Journal of Fish Biology
Volume: 609
Pages: 907-922
URL: ftp://ftp.water.ca.gov/DES/BDCP/Hobbs%20Bennet%20et_al%202006.pdf
Relevance to X2 and LSZ: Delta smelt in the north channel of Suisun Bay exhibited higher densities, larger sizes, increased somatic condition, and greater feeding success, compared to the south channel. Longfin smelt exhibited similar densities, size distributions, and feeding success between both channels, but generally showed poorer somatic condition for the south channel, potentially due to energetic costs associated with documented vertical migration behavior. Overall, the physical conditions of the north channel provided superior habitat for both species, while the south channel afforded only marginal habitat for longfin smelt and very poor habitat for delta smelt. Therefore, the north channel of Suisun Bay acts as critical nursery habitat by providing better feeding and growing conditions.

11: Response of anchovies dampens effects of the invasive bivalve *Corbula amurensis* on the San Francisco Estuary foodweb
Author(s): W. J. Kimmerer
Year: 2006
Journal: Marine Ecology Progress Series
Volume: 324
Pages: 207-218
URL: http://www.int-res.com/articles/meps2006/324/m324p207.pdf
Relevance to X2 and LSZ: When *C. amurensis* invaded the San Francisco Estuary, the distribution of northern anchovy *Engraulis mordax* shifted toward higher salinity, reducing summer abundance by 94% in the low-salinity region of the estuary. The shift in spatial distribution appears to have been a direct behavioral response to reduced food. Bioenergetic calculations showed reduced consumption of zooplankton by all planktivores, including mysids, after *C. amurensis* became abundant, and the anchovy left the low-salinity region of the estuary. This reduced consumption appears to have mitigated effects of the loss of phytoplankton productivity due to increased grazing by the invader, making a greater

proportion of the zooplankton productivity available to other fish species.

12: The role of ammonium and nitrate in spring bloom development in San Francisco Bay
Author(s): R. C. Dugdale, F. P. Wilkerson, V. E. Hogue, and A. Marchi
Year: 2007
Journal: Estuarine, Coastal, and Shelf Science
Volume: 73
Pages: 17-29
URL: http://www.usc.edu/org/seagrant/Publications/PDFs/Dugdale_etal2_007.pdf
Relevance to X2 and LSZ: The authors suggest that San Francisco Bay's substantial inventory of nitrate (NO_3) is unavailable to the resident phytoplankton most of the year due to the presence of ammonium (NH_4) at inhibitory concentrations that prevent NO_3 uptake. Detailed analysis of spring blooms in three embayments over 3 years shows a consistent sequence of events that starts with improved irradiance conditions through stabilization of the water column by stratification or reduced tidal activity. Second, NH_4 concentrations are reduced to a critical range, 1 to 4 μmol per liter, through dilution by precipitation and by phytoplankton uptake. Third, the drawdown of NH_4 enables rapid uptake of NO_3 and subsequent increase in chlorophyll.

13: Multidecadal trends for three declining fish species: habitat patterns and mechanisms in the San Francisco Estuary, California, USA
Author(s): F. Feyrer, M. L. Nobriga, and T. R. Sommer
Year: 2007
Journal: Canadian Journal of Fisheries and Aquatic Sciences
Volume: 64
Pages: 723-734
URL: http://www.water.ca.gov/aes/docs/FeyrerNobrigaSommer2007.pdf
Relevance to X2 and LSZ: General additive model (GAM) predictions for delta smelt, striped bass, and threadfin shad, exhibited significant long-term declines in habitat suitability in the estuary, especially in San Pablo Bay and the South Delta. Simple regression models suggest that water quality may be an important factor in the decline of delta smelt, at least during the past two decades, when food availability was severely reduced by the invasion of *C. amurensis*. The findings corroborate previous hypotheses that the area of suitable physical and chemical habitat has played a role in the decline in fish abundance.

14: Long-term trends in summertime habitat suitability for delta smelt, *Hypomesus transpacificus*
Author(s): M. Nobriga, T. Sommer, F. Feyrer, and K. Fleming
Year: 2008
Journal: San Francisco Estuary and Watershed Science
Volume: 6
Number: 1
Pages: Article 1
URL: http://www.water.ca.gov/aes/docs/NobrigaSummerHabitat.pdf
Relevance to X2 and LSZ: The findings from this study support the hypothesis that basic water quality parameters are predictors of delta smelt relative abundance, but only at regional spatial scales. The authors identified three distinct geographic regions that had similar long-term trends in delta smelt capture probabilities: a primary habitat region centered on the confluence of the Sacramento and San Joaquin rivers and two marginal habitat regions, one centered on Suisun Bay and the other on the San Joaquin River and southern Sacramento-San Joaquin Delta. Three water quality variables— specific conductance (salinity), Secchi depth (clarity), and temperature—measured concurrently with fish catches all interact to influence delta smelt occurrence (distribution) in the upper San Francisco estuary and are thus indicators of abiotic habitat suitability. Long-term associations of water quality variation

and relative abundance were most notable on the perimeter of the species' distribution outside of the Confluence region. Delta smelt relative abundance in the Suisun region varied in association with specific conductance, which is a function of river inflow variation. The San Joaquin region had the warmest water temperatures and the highest water clarity, which increased strongly in this region during 1970–2004. Increasing water clarity, as the authors suggest, is a long-term habitat constriction for delta smelt and a major reason for its absence in the San Joaquin region during summer.

15: Phytoplankton in the upper San Francisco Estuary: recent biomass trends, their causes and their trophic significance
Author(s): A. D. Jassby
Year: 2008
Journal: San Francisco Estuary and Watershed Science
Volume: 6
Number: 1
Pages: Article 2
URL: http://escholarship.org/uc/item/71h077r1
Relevance to X2 and LSZ: The paper examines the effect of flow on phytoplankton biomass in the context of an empirical model that attempts to separate contemporaneous flow conditions from other, perhaps unidentified, forces behind the long-term trend. Regional phytoplankton biomass trends during 1996–2005 are positive in the Delta and neutral in Suisun Bay. The trend in Delta primary productivity is also positive. Changes in phytoplankton biomass
and production during the last decade are therefore unlikely to be the cause of more recent metazoan declines. Freshwater flow variability and its effect on particle residence time are the main source of interannual phytoplankton variability in the Delta, including the upward trend. This conclusion is supported by trend analyses; the concurrence of these time trends at widely-separated stations; empirical models at the annual and monthly time scales; particle residence time estimates; and experience from other estuaries. The reason behind Suisun Bay phytoplankton's low responsiveness to flow variability appears to be *C. amurensis*, which has maintained the phytoplankton community mostly at low levels by vigorous filter-feeding. In the past, flows into Suisun Bay generally diluted the higher phytoplankton concentrations within the bay; now they bring in higher phytoplankton concentrations from upstream. Accordingly, Jassby suggests loading of phytoplankton and phytoplankton-derived detritus accounts for much of the phytoplankton carbon supply to Suisun Bay. In the Delta, *Corbicula fluminea* may be conceivably responsible for a significant part of the observed interannual variability in phytoplankton biomass. Macronutrient supply, on the basis of dissolved nutrient levels, does not seem to be important as a determinant of phytoplankton variability. Water temperature increased significantly during 1996–2005. The temperature increase is significant and, at least partially independent of flow changes, but its net effect on the phytoplankton community is unknown because of differential effects on growth and loss processes.

16: Is the response of estuarine nekton to freshwater flow in the San Francisco Estuary explained by variation in habitat volume?
Author(s): W. J. Kimmerer, E. S. Gross, and M. L. MacWilliams
Year: 2009
Journal: Estuaries and Coasts
Volume: 32
Pages: 375-389
URL: http://www.springerlink.com/content/26pr3h5574605083/fulltext.pdf
Relevance to X2 and LSZ: The key finding in this study is that of eight species, only two (American shad and striped bass) had habitat relationships to X2 that appeared consistent with their relationships of abundance (or survival) to X2. The authors conclude that mechanisms other than variation in physical habitat must underlie responses of abundance to

flow for most species. The authors calculated an index of total habitat for each species by combining resource selection functions for salinity and depth with estimates of habitat volume at five different flows using the TRIM3D hydrodynamic model. The resource selection functions for the examined species were consistent for data from different sampling programs with the exception of longfin smelt, which had a peak resource value at salinity near 20 in the Bay Study otter trawl (sampling in deeper water, more seaward) but near 10 or less in the other samples (sampling in shallower water, more landward).

17: Salinity trends, variability, and control in the northern reach of the San Francisco Estuary
Author(s): C. Enright and S. D. Culberson
Year: 2009
Journal: San Francisco Estuary and Watershed Science
Volume: 7
Number: 2
Pages: Article 3
URL: http://escholarship.org/uc/search?entity=jmie_sfews;volume=7;issue=2
Relevance to X2 and LSZ: The key conclusion here is that climate is the primary long-term salinity *variability* driver at the seasonal and annual scale. The water projects influence the trend of the annual and some monthly means in outflow and salinity, but exert far less influence on variability. Notably, both outflow and salinity are generally more variable in the water project era concordant with watershed precipitation. However, the water projects have decoupled long-term trends in annual mean outflow and salinity from long-term trends in climate forcing. Outflow trends downward in opposition to the precipitation trend in the post-project period. The authors also note an apparent reduction in fall outflow from the Delta and salinity variability in the northern reach in the last decade as the water projects have operated more closely to maximum export-inflow ratios.

18: An analysis of pelagic species decline in the upper San Francisco Estuary using multivariate autoregressive modeling (MAR)
Author(s): R. Mac Nally, J. R. Thomson, W. J. Kimmerer, F. Feyrer, K. B. Newman, A. Sih, W. A. Bennett, L. Brown, E. Fleishman, S. D. Culberson, and G. Castillo
Year: 2010
Journal: Ecological Applications
Volume: 20
Number: 5
Pages: 1417-1430
URL: http://online.sfsu.edu/~modelds/Files/References/MacNallyetal2010EcoApps.pdf
Relevance to X2 and LSZ: The authors applied a Bayesian (probabilistic) analysis framework to validate fifty-four relationships representing the state of knowledge of how abiotic habitat factors directly relate to declining fish abundance in the upper San Francisco Estuary and indirectly to these fish populations through the food web. An underlying expert model specified whether particular trophic or covariate effects might be influential. X2 and increased water clarity over the period of analyses were two factors affecting multiple declining taxa (including fishes and their main zooplankton prey). There was a pervasive relationship of spring X2 with abundances of longfin smelt. There is evidence of potential effects of water exports on delta smelt and threadfin shad. Increases in water exports in both winter and spring were negatively associated with abundance of delta smelt and increases in spring exports with abundance of threadfin shad. The results for delta smelt were consistent with multiple effects of temperature, feeding, exports, and introduced species. The results for striped bass are consistent with effects of feeding and water clarity. Covariates (factors thought to be important for one or more of the response variable) explained 51% variation, suggesting that some aspects of the environment that can be managed are associated with the declining fish species (e.g., X2 and exports). Other potential remedial actions would be difficult or impossible to enact (e.g., total removal of *C. amurensis*).

19: Bayesian change-point analysis of abundance trends for pelagic fishes in the upper San Francisco Estuary
Author(s): J. R. Thomson, W. J. Kimmerer, L. R. Brown, K. B. Newman, R. Mac Nally, W. A. Bennett, F. Feyrer, and E. Fleishman
Year: 2010
Journal: Ecological Applications
Volume: 20
Number: 5
Pages: 1431-1448
Relevance to X2 and LSZ: By using multispecies change point models, the authors find strong evidence for a common change point for all POD species in 2002. Abiotic variables, including water clarity, position of X2, and the volume of freshwater exported from the estuary, explained some variation in species' abundances over the time series, but no selected covariates could explain statistically the post-2000 change points for any species. Species-specific, covariate-conditioned change point models indicated step declines in abundances (i.e., abrupt declines that could not be modeled by the included covariates) of delta smelt and longfin smelt in 2004 and of striped bass and threadfin shad in 2002. In a variable-selection model for delta smelt, water clarity and winter exports both had high probability of inclusion and a negative effect. In the variable-selection model for longfin smelt, water clarity and spring X2 had high probability of inclusion. In the variable-selection model for striped bass, water clarity and the autocorrelation term had high probability of inclusion. No variables had high probability of inclusion in the threadfin shad variable selection model. The authors used a hierarchical Bayesian modeling framework, which allows sampling or measurement error to be separated from actual variation in underlying abundances, while fitting a wide variety of process models.

20: Modeling the effects of future outflow on the abiotic habitat of an imperiled estuarine fish
Author(s): F. Feyrer, K. Newman, M. Nobriga, and T. Sommer
Year: 2011
Journal: Estuaries and Coasts
Volume: 34
Pages: 120-128
Relevance to X2 and LSZ: The authors report a 78% decrease in an annual abiotic habitat index for delta smelt over the study period (1967 – 2004). Using the General Additive Model developed by Feyrer et al. (2007), only specific conductance and Secchi depth accounted for a meaningful reduction of null deviance (i.e., unexplained variability). The final model with specific conductance and Secchi depth accounted for 26% of the deviance. The CALSIM II model was used to simulate future X2 scenarios under seven different development (each assuming a constant level of development) and climate change scenarios, representing a range of drier and wetter possibilities. Modeled future conditions produced smaller values of the delta smelt habitat index relative to the modeled present day condition, the only exception being in critical years when all values were similar and low. These modeling results suggest further declines in habitat across all water year types. The authors conclude that recovery targets for delta smelt will be difficult to attain if the modeled habitat conditions are realized. A key part of the concern for delta smelt is that the lowest levels of suitable habitat coincide with the habitat being located further upstream in closer proximity to anthropogenic sources of mortality such as water diversions and certain contaminant sources. Locations of X2 downstream of the confluence of the Sacramento and San Joaquin rivers results in a dramatic increase in the habitat index, when the LSZ encompasses the expansive Suisun and Grizzly Bays, a larger area of suitable habitat.

21: Microzooplankton grazing in green water—results from two contrasting estuaries
Author(s): J. York, B. Costas, and G. McManus
Year: 2011
Journal: Estuaries and Coasts

Volume: 34
Pages: 373-385
URL: http://online.sfsu.edu/~modelds/Files/References/YorkEtAl2010EstuariesCoasts.pdf
Relevance to X2 and LSZ: Using the dilution method to measure seasonal variations in microzooplankton grazing on phytoplankton, the authors found many instances of saturated as well as insignificant grazing in San Francisco Bay. They suggest that saturation in some cases may result from high particle loads and that insignificant grazing may result from extreme saturation of the grazing response due to the need to process non-food particles. There was no evidence of nutrient limitation for phytoplankton growth. In a series of two-point dilutions run in spring and summer 2007, the authors found increasing phytoplankton growth rates and microzooplankton grazing rates with increasing salinity. Grazing rates in San Francisco Bay and Long Island Sound were similar to those found in other estuaries.

22: Shifts in zooplankton community structure: implications for food web processes in the upper San Francisco Estuary
Author(s): M. Winder and A. D. Jassby
Year: 2011
Journal: Estuaries and Coasts
Volume: 34
Pages: 675-690
URL: http://www.springerlink.com/content/b30544u2xx0l235u/fulltext.pdf
Relevance to X2 and LSZ: This paper documents major changes in the zooplankton species composition in Suisun Bay and the Delta between 1972 and 2008, largely associated with direct and indirect effects of introductions of non-native bivalve and zooplankton species. Previously dominant copepod species were essentially replaced by newly introduced species over the 37-year study period. Major changes occurred also within the mysid community, with a strong decline in biomass by the end of the 1980s and species composition changes in the early 1990s. In Suisun Bay, the historically abundant calanoid copepods and rotifers have declined significantly, but their biomass has been compensated to some extent by the introduced cyclopoid *Limnoithona tetraspina*. The increasing dominance of *L. tetraspina* in the early 1990s in Suisun Bay coincided with declining trends in the average micro- and mesozooplankton size in this region. The Delta has also experienced long-term declining biomass trends, particularly of cladocerans and rotifers, although calanoid copepods have increased since the early 1990s due to the introduced *Pseudodiaptomus spp*. However, zooplankton biomass in the Delta has remained at a low level since the mid-1980s. Changes in the biomass, size, and possibly chemical composition of the zooplankton community imply major alterations in pelagic food web processes, including a drop in prey quantity and quality for foraging fish and an increase in the importance of the microbial food web for higher trophic levels.

23: Sudden clearing of estuarine waters upon crossing the threshold from transport to supply regulation of sediment transport as an erodible sediment pool is depleted: San Francisco Bay, 1999
Author(s): D. H. Schoellhamer
Year: 2011
Journal: Estuaries and Coasts
Volume: 34
Pages: 885-899
URL: http://bayplanningcoalition.org/wp-content/uploads/Schoellhamer-2001-sudden-clearing.pdf
Relevance to X2 and LSZ:

The paper presents a quantitative conceptual model of an estuary with an erodible sediment pool and transport or supply regulation of sediment transport. The author offers a hypothesis that the Bay contained an erodible pool of sediment that was depleted in the late 1990s. The hypothesis is supported by an analysis of historical changes in bed sediment volume. The study was motivated by a statistically significant 36% step decrease in SSC in San Francisco Bay from water years 1991–1998 to 1999–2007. This step change in the water year mean SSCs from WY 1998 to 1999 was significant (one-sided rank-sum test $p<0.01$) at all sites except San Mateo Bridge. At the interannual time scale of this study, an erodible sediment pool is the difference between the existing sediment mass and the sediment mass of the estuary at equilibrium (no net deposition or erosion). An erodible sediment pool is depleted when transport-regulated suspension becomes supply-regulated. When regulation of suspended sediment crosses the threshold from transport regulation to supply regulation, suspended mass can rapidly decrease. At the interannual time scale, the erodible sediment pool is larger than at the tidal time scale. Changes in the erodible sediment pool caused by changes in hydrodynamic forcing, specifically decreased tidal prism due to construction fill and levees, are assumed to be negligible. Application of the quantitative conceptual model to San Francisco Bay demonstrates that depletion of an erodible sediment pool in 1999 would cause a sudden decrease in SSC. Supply of hydraulic mining sediment increased bed sediment volume by at least 260 Mm^3 in the late 1800s, almost entirely in Suisun and San Pablo Bay. From the early to mid-1900s, there was a second pulse of sediment about 60% of the hydraulic mining sediment pulse and conceivably caused by urbanization or increased agricultural land use. Without an erodible sediment pool, annual suspended mass would be dependent on river supply and would not suddenly decrease, unless the river supply suddenly decreased. The river supply to San Francisco Bay varies annually and decreased 1.3%/year during the later half of the twentieth century (Hestir et al. submitted). The decreasing watershed sediment supply contributes to decreased SSC but cannot account for the step decrease in SSC. According to the author, changes in the San Francisco Bay ecosystem in the 2000s have been symptomatic of the sudden clearing.

Appendix 4: Notes on Estimating X2

Notes on estimating X2, the distance from the Golden Gate to 2 ppt Salinity (km)

These notes were prepared to accompany an excel workbook (that will be available at the workshop if not before) containing 1930-2011 DAYFLOW and X2 data for use by IEP. The last two pages of these notes contain notes about X2 and outflow values available in CDEC and the now discontinued DWR/IEP HEC-DSS database. A compilation of CDEC outflow (1994-present) and X2 (2007-present) data is available.

NOTE: THE X2 EQUATION (equation 1, below) IS 20 YEARS OLD. MUCH MORE SALINITY AND FLOW DATA ARE NOW AVAILABLE THAN WHEN THE EQUATION WAS FIRST ESTABLISHED 20 YEARS AGO. THERE ARE SIGNIFICANT DISCREPANCIES BETWEEN X2 VALUES IN DAYFLOW AND IN CDEC. PROCEDURES FOR ESTIMATING X2 SHOULD BE REEVALUATED USING ALL CURRENTLY AVAILABLE DATA AND PERHAPS NEW MODELING APPROACHES.

X2 values in DAYFLOW

(http://www.water.ca.gov/dayflow/documentation/dayflowDoc.cfm#Introduction):

According to the DAYFLOW documentation, "The 1994 Bay-Delta agreement established standards for salinity in the estuary. Specifically, the standards determine the degree to which salinity is allowed to penetrate up-estuary, with salinity to be controlled through delta outflow. The basis for the standards is a series of relationships between the salinity pattern and the abundance or survival of various species of fish and invertebrates. These relationships have been expressed in terms of X2, the distance from the Golden Gate to the point where daily average salinity is 2 parts per thousand at 1 meter off the bottom (Jassby et. al. 1995)."

DAYFLOW X2 estimates are available starting on October 1, 1996. In DAYFLOW, X2 is estimated using the Autoregressive Lag Model:

1. $X2(t) = 10.16 + 0.945 * X2(t-1) - 1.487 \log(QOUT(t))$
   where t = current day and t-1 = previous day

Daily X2 Estimates for the 1930-2011 time series in <u>THIS WORKBOOK</u>:

As in DAYFLOW and elsewhere, equation 1 and DAYFLOW's daily "Net Delta Outflow Index" (NDOI) values are used for all daily X2 estimates from 1930-2011. In contrast to previous X2 estimations, however, the outflow value is set to a fixed outflow of 50 cfs for days with negative net Delta outflow. The only exception is June 3 –June 5, 2004, when the X2 estimates given in DAYFLOW are used. See C2, below, for more information.

Additional information for estimating X2

A. **<u>Origin:</u>**
   The X2 equation used in DAYFLOW was first published in Appendix A of the 1993 "Schubel report" (SFEP 2003). It was developed to "fill in the gaps" in a daily X2 time series that was developed by interpolating actual salinity measurements. The equation is an autoregressive model with lag 1 and an additional variable, log outflow. It was fitted with outflow and X2

data for 1975-77 (>1000 data points). The Schubel report Appendix A was written in 1992 by Kimmerer and Monismith based on work by participants in the "Schubel workshop" and especially Alan Jassby who wrote Appendix 2 of the Schubel report. All later equations and publications are based on this work. In Appendix A of the 1993 Schubel report, Kimmerer and Monismith also give an equation for estimating monthly X2 values:

2. X2(t) = 122.2 + 0.3278*X2(t-1) – 17.65log(QOUT(t))
   where t = current month and t-1 = previous month

B. Later X2 equations:

3. Jassby et al 1995: X2(t)= 8 + 0.945*X2(t-1) – 1.5log(QOUT(t))
4. Jassby et al 1995 cited in Monismith, Kimmerer, et al (2002): X2(t)= 10.2 + 0.945*X2(t-1) – 2.3log(QOUT(t))
5. Monismith, Kimmerer, et al (2002): X2(t)= 0.919*X2(t-1) +13.57(QOUT(t)^-0141)
6. DWR Modeling Support Branch 1994: X2(t)= 14.53 + 0.926*X2(t-1) – 2.192log(QOUT(t))

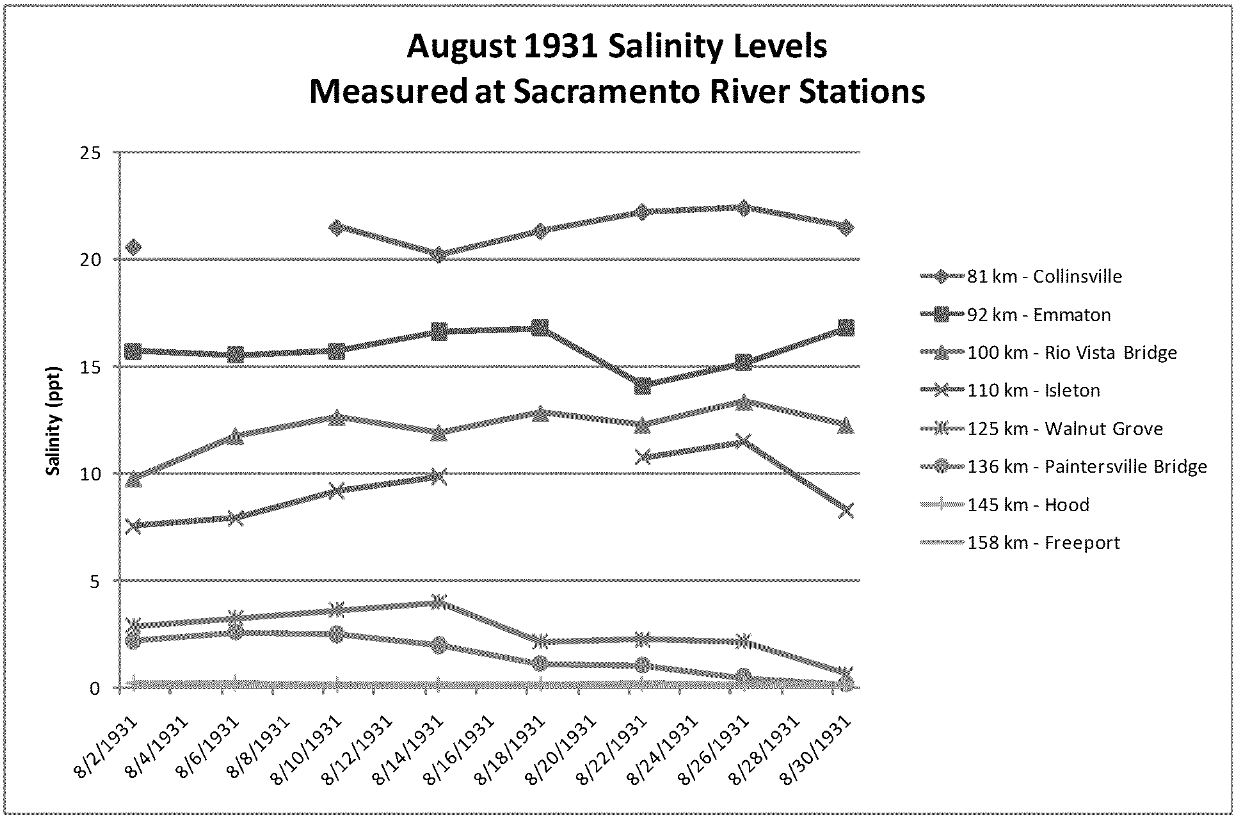
C. Problems with estimating X2 from outflow:

1. Equations 3., 4., and 5. don't give reasonable results – why? (see "X2Computation" worksheet)
2. Negative net Delta outflow: This happens fairly rarely, but it can be associated with extreme salinity intrusion during droughts. Due to spring-neap variations in flow, it is in reality perhaps also more common than the calculated Net Delta Outflow Index in DAYFLOW would suggest, see http://www.water.ca.gov/dayflow/ndoVsNdoi/ . In equation 1, X2 is estimated with log outflow. The log of a negative number does not exist. Moreover, daily X2 estimation requires an X2 value the previous day and gaps in the daily time series should thus be filled. In the Schubel report Appendix A, Kimmerer & Monismith noted that negative outflows were likely "being underestimated" in DAYFLOW (page A-6). They recommended setting "the value of log outflow for [days with negative outflow] to a minimum outflow of 316 cfs." They did not give a reason for this particular value. Following this recommendation produces what generally look like reasonable results.

   I decided, however, to use a substitution value of 50 cfs because this produces X2 estimates that correspond more closely to some observed salinity values, as follows. This should, however, be examined more carefully with additional data. Note that the choice of substitution value makes a difference only during the relatively rare negative outflow periods and a few months immediately following these periods.

   a. Net Delta outflow was negative during June 3-5, 2004, due to the Jones Tract levee break. Instead of using a substitution value, DAYFLOW used X2 values calculated from actual EC data measured at Pittsburg and Antioch, see http://www.water.ca.gov/dayflow/docs/2004comments.pdf . Estimating X2 with equation 1 with an outflow substitution value of 316 underestimated X2 during the three negative outflow days in June 2004 and for about 2 months afterward. An outflow substitution value of 50 produced much better agreement, see X2Computation worksheet.
   b. Net Delta outflow was often negative for prolonged periods in the extreme drought years of the 1930s. Salinity data for some of these years is available in a 1931 report (http://www.archive.org/details/variationcontrol27calirich) and DWR's Delta Atlas (http://baydeltaoffice.water.ca.gov/DeltaAtlas/04-WaterQuality.pdf) shows maximum salinity intrusions for 1921-1943. For 1931, the Delta Atlas shows that "1000 parts of

chloride per million parts of water" (about 1.8 ppt salinity) were measured on the Sacramento River between Courtland and Hood, i.e. at approximately 140 km from the Golden Gate. The 1931 report shows salinity of >2ppt at Paintersville Bridge (approx. 136 km from the GG) in the first half of August 1931 (see Figure below). Using a negative outflow substitution value of 316 produces an average August 1931 X2 value of 116.5 km. A substitution value of 50 produces an average August 1931 X2 value of 137 km, i.e. much better agreement with the recorded salinity values.



References:

- 1931 Salinity report, http://www.archive.org/details/variationcontrol27calirich
- SFEP 1993 with Kimmerer & Monismith Appendix A, 1992, http://www.epa.gov/region9/water/watershed/sfbay-delta/pdf/Schubel-Report.pdf
- DWR 1994, http://www.swrcb.ca.gov/waterrights/water_issues/programs/bay_delta/wq_control_plans/1995wqcp/admin_records/part03/063.pdf
- Jassby et al 1995, http://sfbay.wr.usgs.gov/publications/pdf/jassby_1995_isohaline.pdf
- Monismith et al 2002, http://www-ce.stanford.edu/faculty/monismith/MonismithEtAl2002JPO.pdf
- DWR's Delta Atlas (http://baydeltaoffice.water.ca.gov/DeltaAtlas/04-WaterQuality.pdf

Daily X2 estimates on CDEC (pers com. Joni Hirabayashi, DWR, 9/12/2011)

In CDEC, daily X2 data starting in 2007 is available under the station name "CX2," see http://cdec.water.ca.gov/cgi-progs/stationInfo?station_id=CX2 .

On 9/16 and 9/27, 2011, CDEC posted the following description of the CX2 computation and data flags:
The X2 value for station CX2 is linearly interpolated for the 2.64 uS/cm EC location among these four river mileages measuring from the SF Golden Gate Bridge: Martinez (MRZ, 56 km), Port Chicago (PCT, 64 km), Chipps Island (74 km) and Collinsville (CLL, 81 km).

"v" flag : the calculated value is less than 56.0 km or greater than 81.0 km.

On 9/12/2011, I obtained the following additional information from Joni Hirabayashi, DWR:

The X2 value for CDEC "station" CX2 (http://cdec.water.ca.gov/cgi-progs/stationInfo?station_id=CX2) is interpolated from the daily EC at the four X2 stations: Martinez (MRZ, 56 km), Port Chicago (PCT, 64 km), Mallard (MAL, 74 km) and Collinsville (CLL, 81 km). The formula was developed by engineers in DWR's O&M Operations Control Office.

CX2=(((2.64 – wEC) * (wkm – ekm))/ (wEC – eEC))+ wkm
Where:
wEC = daily EC of the westerly Station
eEC = daily EC of the easterly Station
wkm = kilometers of the westerly Station
ekm = kilometers of the easterly Station

Where EC =2.64 falls among the four stations determines which station pair is used. X2 values out of the 56 – 81 km range are not considered valid (Martinez EC < 2.64 or Collinsville EC > 2.64).

Daily Net Delta Outflow Index estimates on CDEC

Daily Delta Outflow starting in 1994 is available at http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=DTO . There is no documentation posted about how this is calculated.

On 2/14/2012, I obtained the following information from Andy Chu, DWR:
"DTO" stands for DELTA TOTAL OUTFLOW. It is a calculated value, it is not measured. This term is commonly interchanged with "NET DELTA OUTFLOW INDEX", or NDOI, as reported in DAYFLOW. However, DTO values posted on the CDEC are typically NOT cross-checked on a real-time basis. More accurate NDOI numbers that are updated every business day are available at http://www.water.ca.gov/swp/operationscontrol/deltaops.cfm , "Hydrologic Conditions Summary."

CDEC DTO is calculated as follows:

NET DELTA OUTFLOW INDEX = INFLOW INTO DELTA - NET DELTA CONSUMPTIVE USE - CVP/SWP EXPORTS - CONTRA COSTA CANAL - BARKER SLOUGH PP

Where:
INFLOW INTO DELTA = SACTO RIV FREEPORT + SACTO CO WASTE WT TRTMNT + YOLO BYPASS + EAST SIDE STREAMS + MISCELLANEOUS - FORTHCOMING + SJ RIV FLOW VERNALIS

And:
CVP/SWP EXPORTS = CLIFTON COURT INFLOW - BYRON BETHANY DELIVERIES +

TRACY PP TOTAL

One final note on net Delta outflow:
As mentioned above, "outflow" in DAYFLOW and CDEC is really a calculated "Net Delta Outflow Index" (NDOI), not a measured value. This is in contrast to "Net Delta Outflow," (NDO), which according to the DAYFLOW documentation (http://www.water.ca.gov/dayflow/ndoVsNdoi/) is a more direct estimate of daily average flow based on 15 minute USGS ultrasonic velocity meter (UVM) flow data from four stations. NDO is calculated as the sum of flows from these four stations:

NDO = Rio Vista + Three Mile Slough + Jersey Point + Dutch Slough
Where:
Rio Vista = Sacramento River at Rio Vista UVM
Three Mile Slough = Three Mile Slough at San Joaquin River UVM
Jersey Point= San Joaquin River at Jersey Point UVM
Dutch Slough = Dutch Slough at Jersey Island UVM

NDO data have been available in an U.S. Army Corps of Engineers' Hydrologic Engineering Center Data Storage System (HEC-DSS) database system that was maintained by the Department of Water Resources and the IEP. This database was recently discontinued. Archived historical HEC-DSS data is available for downloading as DSS data files at http://www.water.ca.gov/iep/products/data/dssnotice.cfm .

Appendix 5: Workshop Agenda and Process

BEGINS ON NEXT PAGE

Technical Workshop on Estuarine Habitat in the Bay Delta Estuary

Managing the Low Salinity Zone to Protect Estuarine Habitat and Aquatic Life

27 March 2012
9:00 am – 4:30 pm
(please arrive by 8:30)
Cal/EPA Coastal Room, 2nd Floor
1001 "I" Street, Sacramento 95814

Purposes of the Workshop

❖ Increase our collective understanding about the attributes of estuarine habitat, and the tools we have for protecting it.

❖ Characterize the response of biological indicators and ecological processes to changing locations of the low salinity zone (LSZ).

❖ Generate scientific information that EPA and others can translate into recommendations that support the State's Comprehensive Review of the 2006 Water Quality Control Plan (WQCP) for the Bay Delta Estuary.

Workgroup Questions[207]

1. What are the key points of scientific agreement, disagreement, and uncertainty surrounding estuarine habitat and aquatic life in the Bay Delta Estuary? How can scientists and agencies "manage the uncertainty" while advancing the protection of estuarine habitat and aquatic life?

2. What is needed to update and improve the State's current approach of protecting estuarine habitat with a springtime salinity standard (FEB-JUN)? Which scientific discoveries and modeling techniques emerging since 1995 should be applied toward managing the LSZ?

3. (a) What are the drivers in the quantity of estuarine habitat during each season of the year?
(b) What are the drivers in the quality of estuarine habitat during each season of the year?
(c) What biological indicators respond to changing locations of the LSZ east of the Carquinez Strait? Please record your ideas on the attached chart of biological indicators and metrics.

4. Given the historical and present-day relationships between the LSZ and the landscape of the Bay Delta, how can models be used to forecast the response of selected biological indicators to changing precipitation patterns, rising sea levels, and restoration scenarios?

Agenda

8:30 – 9:00 Arrive; get settled; enjoy bagels, coffee, and juice

207 Tim Vendlinski drafted these questions with excellent input and suggestions from Brock Bernstein, Erin Foresman, Robin Grossinger, Bruce Herbold, Michael MacWilliams, B.J. Miller, Stephen Monismith, and Karen Schwinn.

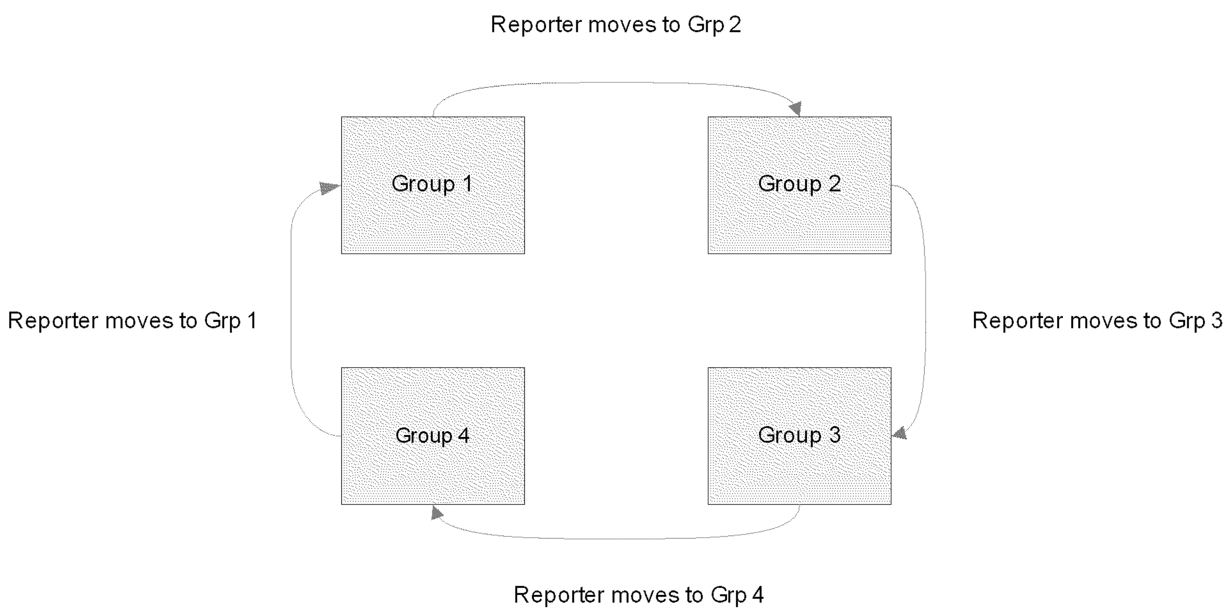
9:00 – 9:10	Welcome and introductions	Karen Schwinn (EPA)
9:10 – 9:20	Agenda overview	Brock Bernstein
9:20 –9:45	Historical Perspectives on the Estuarine Gradient	Robin Grossinger Aquatic Science Center
9:45 –10:10	Modeling Estuarine Processes using SUNTANS	Stephen Monismith Stanford University
10:10 –10:35	Modeling Estuarine Processes using UnTRIM	Michael MacWilliams Delta Modeling Assoc.
10:35–10:40	Reflections on presentations and transition to workgroups	Brock Bernstein
10:40 – 10:50	Workgroup instructions and assignments	Brock Bernstein
10:50 – 12:15	First workgroup session – Prepare first draft of discussion summaries	
12:15 – 1:30	**Working lunch** Second workgroup session – Review and revise discussion summaries	
1:30 – 2:30	Third workgroup session – Review and revise discussion summaries	
2:30 – 2:45	**Break**	
2:45 – 4:15	Group discussion – discussion summaries	Brock Bernstein
4:15 – 4:30	Wrap up and adjourn	Brock Bernstein

Process for Technical Teams

The following workshop process is intended to increase the amount of direct interaction among participants, accelerate the refinement of ideas and products through multiple rounds of review and revision, and ensure that participants have the opportunity to address all topics.

- Break into four pre-assigned technical teams of equal size.

- Designate a team leader and reporter for each team (already done).
- Assign each team (and each reporter) one of the four workshop questions.
- The reporters are paired with the questions and will rotate among the four teams (see figure below). This builds momentum toward enriching the answer to each question, and provides continuity as each question is cycled from team to team.
- Team leaders are charged with keeping their team focused on the task at hand, bringing the best work out of each individual, synthesizing ideas to make conceptual breakthroughs, and ensuring ideas are accurately captured and conveyed to the reporter.
- **First session:** Each team responds to the assigned question.
- Reporters and questions rotate to the next team.
- **Second session:** Reporters brief their new team on the progress made by the previous team toward answering the assigned question. Each team critiques and revises the previous team's product.
- Reporters and questions rotate again.
- **Third session:** Repeat the briefing, critique, and revision of the previous group's product.
- **Group Discussion:** The workshop facilitator will reconvene all the workshop participants. Reporters and team leaders will: (i) describe how the answer(s) to each question evolved as they moved from team to team; and (ii) summarize the key points catalyzed during the collaborative process.



BIOLOGICAL INDICATOR | METRIC

FISH, SHELLFISH, AND OTHER ORGANISMS	

FOOD PRODUCTION	

PRODUCTIVITY OF THE PHOTIC ZONE	

ECOSYSTEM PROCESSES	

CONTAMINANTS	

SITE SPECIFIC STRESSORS	

S A M P L E BIOLOGICAL INDICATOR	S A M P L E METRIC
RESPONSE OF FISH STUDIED AT "X2" WORKSHOPS	
Neomysis mercedis	Metric TBD
Crangon franciscorum	Metric TBD
Molluscs	Metric TBD
Striped bass	Metric TBD
Starry flounder	Metric TBD
Longfin smelt	Metric TBD

FOOD PRODUCTION	
Area of Low Salinity Zone	Hectares
Volume of Low Salinity Zone	Cubic Meters
Time LSZ Spends in Proximity to Productive Habitat	Minutes

PRODUCTIVITY OF THE PHOTIC ZONE	
Depth of Penetration by Sunlight through Water Surface	Centimeters
Turbidity	Nephelometric **Turbidity Unit** (NTU)

ECOSYSTEM PROCESSES	
Diversity of Aquatic Habitat at Four Cross Sections	Numerical Index TBD for Habitat Structure for Fish, e.g., # of feeding spots, # of hiding spots.
Diversity of Flow Patterns at Four Cross Sections	Metric TBD
Interfaces of Currents with Accumulations of Food	Metric TBD

CONTAMINANTS	
Ammonium	Inhibit diatoms/promote microcystis (μmol L^{-1})[208]
Selenium	Biological capture by overbite clams (μg L^{-1})[209]

SITE SPECIFIC STRESSORS	
Time LSZ Spends in Proximity to Outfalls	Minutes
Time LSZ Spends in Proximity to Pumps	Minutes
Time LSZ Spends in Proximity to *Egeria* Beds	Minutes
Time LSZ Spends in Proximity to Deep Channels	Minutes
Time LSZ Spends in Proximity to Power Plants	Minutes
Time LSZ Spends in Proximity to CVP/SWP Effects	Minutes

208 See Dugdale's model
209 See models by Luoma & Presser (fate of Se) and by Jan Thompson (clam abundance)

Appendix 6: Workgroup Members and Assignments

Note that reporters did not remain with their original workgroups but rotated from workgroup to workgroup with their assigned question.

Les Grober (Question 1): Group C to Group B to Group A
Jon Rosenfeld (Question 2): Group D to Group C to Group B
Ted Sommer (Question 3): Group A to Group D to Group C
Steve Culberson (Question 4): Group B to Group A to Group D

Participating scientist	**Affiliation**	**Role**
Workgroup A		
Val Connor	Water contractors	Team Leader
Jon Burau	US Geological Survey	
Mike Chotkowski	US Fish & Wildlife Service	
Robin Grossinger	San Francisco Estuary Inst.	
Ted Sommer	Dept. Water Resources	Reporter Question 3
Mark Stacy	UC Berkeley	
Workgroup B		
Larry Brown	US Geological Survey	Team Leader
Steve Culberson	US Fish & Wildlife Service	Reporter Question 4
Kathy Hieb	Dept. Fish & Game	
Stephen Monismith	Stanford Univ.	
Erwin van Nieuwenhuyse	US Bureau of Reclamation	
Matt Nobriga	US Fish & Wildlife Service	
Workgroup C		
Anke Mueller-Solger	Interagency Ecological Program & DSC	Team Leader
Bill Bennett	UC Davis	
Les Grober	State Water Resources Control Board	Reporter Question 1
Bruce Herbold	US Environmental Protection Agency	
Josh Israel	US Bureau of Reclamation	
Michael MacWilliams	Delta Modeling	
BJ Miller	Consultant	
Workgroup D		
Jan Thompson	US Geological Survey	Team Leader
Randy Baxter	Dept. Fish & Game	
Chris Enright	DSC & Dept. Water Resources	
Lenny Grimaldo	US Bureau of Reclamation	
Jon Rosenfield	TBI	Reporter Question 2
Dave Schoellhamer	US Geological Survey	